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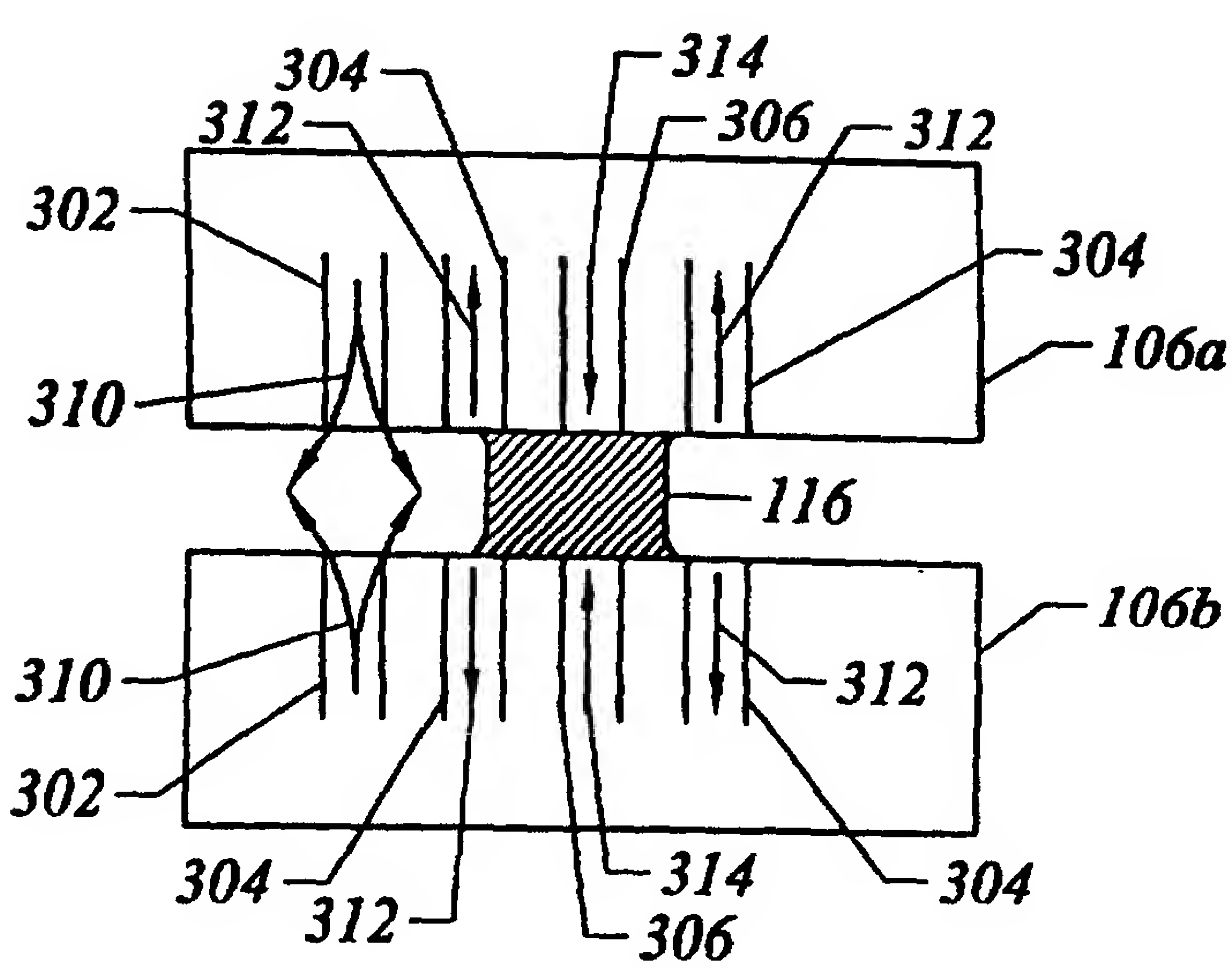
(54) Title: SYSTEM FOR SUBSTRATE PROCESSING WITH MENISCUS, VACUUM, IPA VAPOR, DRYING MANIFOLD



(57) Abstract: An apparatus and method for processing a wafer is provided. The system and method are designed to process a surface of a wafer using a meniscus. The meniscus is controlled and is capable of being moved over the surface of the wafer to enable cleaning, rinsing, chemical processing, and drying. The apparatus can be defined using a number of configurations to enable specific processing of the wafer surface using the meniscus, and such configurations can include the use of proximity heads.

WO 2004/030051 A2

System for Substrate Processing with Meniscus, Vacuum, IPA vapor, Drying Manifold

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to semiconductor wafer processing, cleaning, and drying and, more particularly, to apparatuses and techniques for more efficiently adding and removing fluids from wafer surfaces while reducing contamination and decreasing wafer processing costs.

2. Description of the Related Art

In the semiconductor chip fabrication process, it is well-known that there is a need to clean and dry a wafer where a fabrication operation has been performed that leaves unwanted residues on the surfaces of wafers. Examples of such a fabrication operation include plasma etching (*e.g.*, tungsten etch back (WEB)) and chemical mechanical polishing (CMP). In CMP, a wafer is placed in a holder which pushes a wafer surface against a rolling conveyor belt. This conveyor belt uses a slurry which consists of chemicals and abrasive materials to cause the polishing. Unfortunately, this process tends to leave an accumulation of slurry particles and residues at the wafer surface. If left on the wafer, the unwanted residual material and particles may cause, among other things, defects such as scratches on the wafer surface and inappropriate interactions between metallization features. In some cases, such defects may cause devices on the wafer to become inoperable. In order to avoid the undue costs of discarding wafers having inoperable devices, it is therefore necessary to clean the wafer adequately yet efficiently after fabrication operations that leave unwanted residues.

After a wafer has been wet cleaned, the wafer must be dried effectively to prevent water or cleaning fluid remnants from leaving residues on the wafer. If the cleaning fluid on the wafer surface is allowed to evaporate, as usually happens when droplets form, residues or contaminants previously dissolved in the cleaning fluid will remain on the

wafer surface after evaporation (e.g., and form spots). To prevent evaporation from taking place, the cleaning fluid must be removed as quickly as possible without the formation of droplets on the wafer surface. In an attempt to accomplish this, one of several different drying techniques are employed such as spin drying, IPA, or Marangoni drying. All of these drying techniques utilize some form of a moving liquid/gas interface on a wafer surface which, if properly maintained, results in drying of a wafer surface without the formation of droplets. Unfortunately, if the moving liquid/gas interface breaks down, as often happens with all of the aforementioned drying methods, droplets form and evaporation occurs resulting in contaminants being left on the wafer surface.

The most prevalent drying technique used today is spin rinse drying (SRD). Figure 1 illustrates movement of cleaning fluids on a wafer 10 during an SRD drying process. In this drying process, a wet wafer is rotated at a high rate by rotation 14. In SRD, by use of centrifugal force, the water or cleaning fluid used to clean the wafer is pulled from the center of the wafer to the outside of the wafer and finally off of the wafer as shown by fluid directional arrows 16. As the cleaning fluid is being pulled off of the wafer, a moving liquid/gas interface 12 is created at the center of the wafer and moves to the outside of the wafer (i.e., the circle produced by the moving liquid/gas interface 12 gets larger) as the drying process progresses. In the example of Figure 1, the inside area of the circle formed by the moving liquid/gas interface 12 is free from the fluid and the outside area of the circle formed by the moving liquid/gas interface 12 is the cleaning fluid. Therefore, as the drying process continues, the section inside (the dry area) of the moving liquid/gas interface 12 increases while the area (the wet area) outside of the moving liquid/gas interface 12 decreases. As stated previously, if the moving liquid/gas interface 12 breaks down, droplets of the cleaning fluid form on the wafer and contamination may occur due to evaporation of the droplets. As such, it is imperative that droplet formation and the subsequent evaporation be limited to keep contaminants off of the wafer surface. Unfortunately, the present drying methods are only partially successful at the prevention of moving liquid interface breakdown.

In addition, the SRD process has difficulties with drying wafer surfaces that are hydrophobic. Hydrophobic wafer surfaces can be difficult to dry because such surfaces

repel water and water based (aqueous) cleaning solutions. Therefore, as the drying process continues and the cleaning fluid is pulled away from the wafer surface, the remaining cleaning fluid (if aqueous based) will be repelled by the wafer surface. As a result, the aqueous cleaning fluid will want the least amount of area to be in contact with the hydrophobic wafer surface. Additionally, the aqueous cleaning solution tends cling to itself as a result of surface tension (i.e., as a result of molecular hydrogen bonding). Therefore, because of the hydrophobic interactions and the surface tension, balls (or droplets) of aqueous cleaning fluid forms in an uncontrolled manner on the hydrophobic wafer surface. This formation of droplets results in the harmful evaporation and the contamination discussed previously. The limitations of the SRD are particularly severe at the center of the wafer, where centrifugal force acting on the droplets is the smallest. Consequently, although the SRD process is presently the most common way of wafer drying, this method can have difficulties reducing formation of cleaning fluid droplets on the wafer surface especially when used on hydrophobic wafer surfaces.

Therefore, there is a need for a method and an apparatus that allows quick and efficient cleaning, processing and drying of a semiconductor wafer, but at the same time reducing the formation of numerous water or cleaning fluid droplets which may cause contamination to deposit on the wafer surface. Such deposits as often occurs today reduce the yield of acceptable wafers and increase the cost of manufacturing semiconductor wafers.

SUMMARY OF THE INVENTION

Broadly speaking, the present invention fills these needs by providing a cleaning and drying apparatus that is capable of removing fluids from wafer surfaces quickly while at the same time reducing wafer contamination. It should be appreciated that the present invention can be implemented in numerous ways, including as a process, an apparatus, a system, a device or a method. Several inventive embodiments of the present invention are described below.

In one embodiment, a substrate preparation system is provided which includes a drying system where the drying system includes at least one proximity head for drying a substrate. The system also includes a cleaning system for cleaning the substrate.

In another embodiment, a cluster architecture system for processing a wafer is provided. The system includes an integrated drying system where the integrated drying system includes at least one proximity head for drying a substrate. The system further includes processing modules coupled to the integrated drying system where the processing modules are selected from one or more of a chemical mechanical planarization module, a megasonic processing module, a cleaning module, and an etching module.

In yet another embodiment, a method for cluster processing a substrate is provided. The method includes performing at least one of etching a substrate, planarizing the substrate, megasonically processing the substrate, cleaning the substrate. The method also includes drying of the substrate. The drying includes applying a first fluid onto a first region of a surface of the substrate, applying a second fluid onto a second region of the surface of the substrate, and removing the first fluid and the second fluid from the surface of the substrate. The removing occurs from a third region that substantially surrounds the first region. The second region substantially surrounds at least a portion of the third region, and the applying and the removing being capable of forming a controlled fluid meniscus.

In one embodiment, a substrate preparation system is provided which includes a head for use in preparing a wafer surface including a first surface of the head where the first surface capable of being placed in close proximity to the wafer surface. The head also includes a first conduit region on the head where the first conduit region is defined for delivery of a first fluid to wafer of the surface and the first conduit region is defined in a center portion of the head. The head further includes a second conduit region on the head where the second conduit region being configured to surround the first conduit region, and the head also includes a third conduit region on the head where the third conduit region is defined for delivery of a second fluid to the wafer surface, and the third conduit region defines a semi-enclosure of the first conduit region and the second conduit region. The second conduit region enables a removal of the first fluid and the second fluid, and wherein the delivery of the first fluid and the second fluid combined with the removal by the third conduit region of the head defines a controllable meniscus that is defined between the head and the wafer surface when in operation and the head is proximate to the wafer surface.

In another embodiment, a substrate preparation system is provided which includes a head having a head surface where the head surface is proximate to a surface of the substrate when in operation. The head also includes at least one of a first conduit for delivering a first fluid to the surface of the substrate through the head and at least one of a second conduit for delivering a second fluid to the surface of the substrate through the head where the second fluid being different than the first fluid. The head further includes at least one of a third conduit for removing each of the first fluid and the second fluid from the surface of the substrate where the at least one of the third conduit is located to substantially surround the at least one of the first conduit, wherein the at least one of the first conduit, the at least one of the second conduit, and the at least one of the third conduit act substantially simultaneously when in operation. The at least one of the second conduit is located to substantially surround at least a portion of the at least one of the third conduit.

In yet another embodiment, a method for preparing a wafer surface is provided that includes supplying a first fluid at a first region on the wafer surface, surrounding the first region with a vacuum region, and semi-enclosing the vacuum region with an applied surface tension reducing fluid region where the semi-enclosing defines an opening that leads to the vacuum region. The method also includes scanning the first region where the vacuum region and the applied surface tension reduces fluid region over the wafer surface where the scanning leads with the opening.

In another embodiment, a wafer preparation module is provided which includes a wafer brush scrubbing unit where the wafer brush scrubbing unit is capable of scrubbing a wafer while applying cleaning fluids to the wafer. The module also includes a wafer drying insert where the wafer drying insert is capable of being integrated into the wafer brush scrubbing unit where the wafer drying insert including a proximity head for drying a surface of the wafer without contacting the surface.

In one embodiment, a method for processing a substrate is provided which includes generating a fluid meniscus on the surface of the vertically oriented substrate, and moving the fluid meniscus over the surface of the vertically oriented substrate to process the surface of the substrate.

In another embodiment, a substrate preparation apparatus to be used in substrate processing operation is provided which includes arm capable of vertical movement between a first edge of the substrate to a second edge of the substrate. The apparatus further includes a head coupled to the arm, the head being capable of forming a fluid meniscus on a surface of the substrate and capable of being moved over the surface of the substrate.

In yet another embodiment, a manifold for use in preparing a wafer surface is provided. The manifold includes a first process window in a first portion of the manifold being configured generate a first fluid meniscus on the wafer surface. The manifold further includes a second process window in a second portion of the manifold being configured to generate a second fluid meniscus on the wafer surface.

The advantages of the present invention are numerous. Most notably, the apparatuses and methods described herein efficiently dry and clean a semiconductor wafer while reducing fluids and contaminants remaining on a wafer surface. Consequently, wafer processing and production may be increased and higher wafer yields may be achieved due to efficient wafer drying with lower levels of contamination. The present invention enables the improved drying and cleaning through the use of vacuum fluid removal in conjunction with fluid input. The pressures generated on a fluid film at the wafer surface by the aforementioned forces enable optimal removal of fluid at the wafer surface with a significant reduction in remaining contamination as compared with other cleaning and drying techniques.

In addition, the present invention may utilize application of an isopropyl alcohol (IPA) vapor and deionized water towards a wafer surface along with generation of a vacuum near the wafer surface at substantially the same time. This enables both the generation and intelligent control of a meniscus and the reduction of water surface tension along a deionized water interface and therefore enables optimal removal of fluids from the wafer surface without leaving contaminants. The meniscus generated by input of IPA, DIW and output of fluids may be moved along the surface of the wafer to clean and dry the wafer. Therefore, the present invention evacuates fluid from wafer surfaces with

extreme effectiveness while substantially reducing contaminant formation due to ineffective drying such as for example, spin drying.

Moreover the present invention also can be incorporated into numerous types of systems to generate wafer processing systems with cluster tools giving the systems multiple types of processing capabilities. By having a system that can conduct different types of wafer processing, wafers can be processed in a more efficient manner. By having different types of cluster tools in the wafer processing system, there may be less time in wafer transport time because the modules/tools are integrated on one system. In addition, there may space savings so less footprint is needed to house the wafer processing apparatuses. Therefore, the present invention may be incorporated into any suitable variety of systems to make wafer processing more efficient and cost effective.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements.

Figure 1 illustrates movement of cleaning fluids on a wafer during an SRD drying process.

Figure 2A shows a wafer cleaning and drying system in accordance with one embodiment of the present invention.

Figure 2B shows an alternate view of the wafer cleaning and drying system in accordance with one embodiment of present invention.

Figure 2C illustrates a side close-up view of the wafer cleaning and drying system holding a wafer in accordance with one embodiment of the present invention.

Figure 2D shows another side close-up view of the wafer cleaning and drying system in accordance with one embodiment of the present invention.

Figure 3A shows a top view illustrating the wafer cleaning and drying system with dual proximity heads in accordance with one embodiment of the present invention.

Figure 3B illustrates a side view of the wafer cleaning and drying system with dual proximity heads in accordance with one embodiment of the present invention.

Figure 4A shows a top view of a wafer cleaning and drying system which includes multiple proximity heads for a particular surface of the wafer in accordance with one embodiment of the present invention.

Figure 4B shows a side view of the wafer cleaning and drying system which includes multiple proximity heads for a particular surface of the wafer in accordance with one embodiment of the present invention.

Figure 5A shows a top view of a wafer cleaning and drying system with a proximity head in a horizontal configuration which extends across a diameter of the wafer 108 in accordance with one embodiment of the present invention.

Figure 5B shows a side view of a wafer cleaning and drying system with the proximity heads in a horizontal configuration which extends across a diameter of the wafer in accordance with one embodiment of the present invention.

Figure 5C shows a top view of a wafer cleaning and drying system with the proximity heads in a horizontal configuration which is configured to clean and/or dry the wafer that is stationary in accordance with one embodiment of the present invention.

Figure 5D shows a side view of a wafer cleaning and drying system with the proximity heads in a horizontal configuration which is configured to clean and/or dry the wafer that is stationary in accordance with one embodiment of the present invention.

Figure 5E shows a side view of a wafer cleaning and drying system with the proximity heads in a vertical configuration enabled to clean and/or dry the wafer that is stationary in accordance with one embodiment of the present invention.

Figure 5F shows an alternate side view of a wafer cleaning and drying system that is shifted 90 degrees from the side view shown in Figure 5E in accordance with one embodiment of the present invention.

Figure 5G shows a top view of a wafer cleaning and drying system with a proximity head in a horizontal configuration which extends across a radius of the wafer in accordance with one embodiment of the present invention.

Figure 5H shows a side view of a wafer cleaning and drying system with the proximity heads and in a horizontal configuration which extends across a radius of the wafer in accordance with one embodiment of the present invention.

Figure 6A shows a proximity head inlet/outlet orientation that may be utilized to clean and dry the wafer in accordance with one embodiment of the present invention.

Figure 6B shows another proximity head inlet/outlet orientation that may be utilized to clean and dry the wafer in accordance with one embodiment of the present invention.

Figure 6C shows a further proximity head inlet/outlet orientation that may be utilized to clean and dry the wafer in accordance with one embodiment of the present invention.

Figure 6D illustrates a preferable embodiment of a wafer drying process that may be conducted by a proximity head in accordance with one embodiment of the present invention.

Figure 6E shows another wafer drying process using another source inlet/outlet orientation that may be conducted by a proximity head in accordance with one embodiment of the present invention.

Figure 6F shows another source inlet and outlet orientation where an additional source outlet may be utilized to input an additional fluid in accordance with one embodiment of the present invention.

Figure 7A illustrates a proximity head performing a drying operation in accordance with one embodiment of the present invention.

Figure 7B shows a top view of a portion of a proximity head in accordance with one embodiment of the present invention.

Figure 7C illustrates a proximity head with angled source inlets performing a drying operation in accordance with one embodiment of the present invention.

Figure 7D illustrates a proximity head with angled source inlets and angled source outlets performing a drying operation in accordance with one embodiment of the present invention.

Figure 8A illustrates a side view of the proximity heads for use in a dual wafer surface cleaning and drying system in accordance with one embodiment of the present invention.

Figure 8B shows the proximity heads in a dual wafer surface cleaning and drying system in accordance with one embodiment of the present invention.

Figure 9A illustrates a processing window in accordance with one embodiment of the present invention.

Figure 9B illustrates a substantially circular processing window in accordance with one embodiment of the present invention.

Figure 9C illustrates a processing window in accordance with one embodiment of the present invention.

Figure 9D illustrates a processing window in accordance with one embodiment of the present invention.

Figure 10A shows an exemplary process window with the plurality of source inlets and as well as the plurality of source outlets in accordance with one embodiment of the present invention.

Figure 10B shows processing regions of a proximity head in accordance with one embodiment of the present invention.

Figure 11A shows a top view of a proximity head with a substantially rectangular shape in accordance with one embodiment of the present invention.

Figure 11B illustrates a side view of the proximity head in accordance with one embodiment of present invention.

Figure 11C shows a rear view of the proximity head in accordance with one embodiment of the present invention.

Figure 12A shows a proximity head with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention.

Figure 12B shows a side view of the proximity head with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention.

Figure 12C shows a back view of the proximity head with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention.

Figure 13A shows a rectangular proximity head in accordance with one embodiment of the present invention.

Figure 13B shows a rear view of the proximity head in accordance with one embodiment of the present invention.

Figure 13C illustrates a side view of the proximity head in accordance with one embodiment of present invention.

Figure 14A shows a rectangular proximity head in accordance with one embodiment of the present invention.

Figure 14B shows a rear view of the rectangular proximity head in accordance with one embodiment of the present invention.

Figure 14C illustrates a side view of the rectangular proximity head in accordance with one embodiment of present invention.

Figure 15A shows a proximity head in operation according to one embodiment of the present invention.

Figure 15B illustrates the proximity head as described in Figure 15A with IPA input in accordance with one embodiment of the present invention.

Figure 15C shows the proximity head as described in Figure 15B, but with the IPA flow increased to 24 ml/min in accordance with one embodiment of the present invention.

Figure 15D shows the proximity head where the fluid meniscus is shown where the wafer is being rotated in accordance with one embodiment of the present invention.

Figure 15E shows the proximity head where the fluid meniscus is shown where the wafer is being rotated faster than the rotation shown in Figure 15D in accordance with one embodiment of the present invention.

Figure 15F shows the proximity head where the IPA flow has been increased as compared to the IPA flow of Figure 15D in accordance with one embodiment of the present invention.

Figure 16A shows a top view of a cleaning/drying system in accordance with one embodiment of the present invention.

Figure 16B shows an alternative view of the cleaning/drying system in accordance with one embodiment of the present invention.

Figure 17 illustrates a wafer processing system with front end frame assembly with a drying module in accordance with one embodiment of the present invention.

Figure 18 shows a wafer processing system which has multiple wafer processing tools in accordance with one embodiment of the present invention.

Figure 19 shows a wafer processing system without the etching module in accordance with one embodiment of the present invention.

Figure 20 illustrates a wafer processing system which includes a drying module and a cleaning module in accordance with one embodiment of the present invention.

Figure 21 shows a block diagram of a wafer processing system in accordance with one embodiment of the present invention.

Figure 22A illustrates a proximity head beginning a wafer processing operation where the wafer is scanned vertically in accordance with one embodiment of the present invention.

Figure 22B illustrates a wafer processing continuing from Figure 16A where the proximity head has started scanning the wafer in accordance with one embodiment of the present invention.

Figure 22C shows a continuation of a wafer processing operation from Figure 16B in accordance with one embodiment of the present invention.

Figure 22D illustrates the wafer processing operation continued from Figure 16C in accordance with one embodiment of the present invention.

Figure 22E shows the wafer processing operation continued from Figure 16D in accordance with one embodiment of the present invention.

Figure 22F shows a side view of the proximity heads situated over the top portion of the vertically positioned wafer in accordance with one embodiment of the present invention.

Figure 22G illustrates a side view of the proximity heads during processing of dual surfaces of the wafer in accordance with one embodiment of the present invention.

Figure 23A shows a wafer processing system where the wafer is held stationary in accordance with one embodiment of the present invention.

Figure 23B shows a wafer processing system where the proximity head carrier may be held in place or moved in accordance with one embodiment of the present invention.

Figure 23C shows a wafer processing system where the proximity head extends about a radius of the wafer in accordance with one embodiment of the present invention.

Figure 23D shows a wafer processing system where the proximity head moves vertically and the wafer rotates in accordance with one embodiment of the present invention.

Figure 24A shows a proximity head that may be utilized for vertical scanning of a wafer in accordance with one embodiment of the present invention.

Figure 24B shows a side view of the proximity head in accordance with one embodiment of the present invention.

Figure 24C shows an isometric view of the proximity head in accordance with one embodiment of the present invention.

Figure 25A shows a multi-process window proximity head in accordance with one embodiment of the present invention.

Figure 25B shows a multi-process window proximity head with three process windows in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An invention for methods and apparatuses for cleaning and/or drying a wafer is disclosed. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be understood, however, by one of ordinary skill in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present invention.

While this invention has been described in terms of several preferred embodiments, it will be appreciated that those skilled in the art upon reading the preceding specifications and studying the drawings will realize various alterations, additions, permutations and equivalents thereof. It is therefore intended that the present invention includes all such alterations, additions, permutations, and equivalents as fall within the true spirit and scope of the invention.

Figures 2A through 2D below illustrate embodiments of an exemplary wafer processing system. It should be appreciated that the system is exemplary, and that any other suitable type of configuration that would enable movement of the proximity head(s) into close proximity to the wafer may be utilized. In the embodiments shown, the proximity head(s) may move in a linear fashion from a center portion of the wafer to the edge of the wafer. It should be appreciated that other embodiments may be utilized where the proximity head(s) move in a linear fashion from one edge of the wafer to another diametrically opposite edge of the wafer, or other non-linear movements may be utilized such as, for example, in a radial motion, in a spiral motion, in a zig-zag motion, etc. In addition, in one embodiment, the wafer may be rotated and the proximity head moved in a linear fashion so the proximity head may process all portions of the wafer. It should also be understood that other embodiments may be utilized where the wafer is not rotated but the proximity head is configured to move over the wafer in a fashion that enables processing of all portions of the wafer. In addition, the proximity head and the wafer

cleaning and drying system described herein may be utilized to clean and dry any shape and size of substrates such as for example, 200 mm wafers, 300 mm wafers, flat panels, etc. The wafer cleaning and drying system may be utilized for either or both cleaning and drying the wafer depending on the configuration of the system.

Figure 2A shows a wafer cleaning and drying system 100 in accordance with one embodiment of the present invention. The system 100 includes rollers 102a, 102b, and 102c which may hold and rotate a wafer to enable wafer surfaces to be dried. The system 100 also includes proximity heads 106a and 106b that, in one embodiment, are attached to an upper arm 104a and to a lower arm 104b respectively. The upper arm 104a and the lower arm 104b are part of a proximity head carrier assembly 104 which enables substantially linear movement of the proximity heads 106a and 106b along a radius of the wafer.

In one embodiment the proximity head carrier assembly 104 is configured to hold the proximity head 106a above the wafer and the proximity head 106b below the wafer in close proximity to the wafer. This may be accomplished by having the upper arm 104a and the lower arm 104b be movable in a vertical manner so once the proximity heads are moved horizontally into a location to start wafer processing, the proximity heads 106a and 106b can be moved vertically to a position in close proximity to the wafer. The upper arm 104a and the lower arm 104b may be configured in any suitable way so the proximity heads 106a and 106b can be moved to enable wafer processing as described herein. It should be appreciated that the system 100 may be configured in any suitable manner as long as the proximity head(s) may be moved in close proximity to the wafer to generate and control a meniscus as discussed below in reference to Figures 6D through 8B. It should also be understood that close proximity may be any suitable distance from the wafer as long as a meniscus as discussed in further reference to Figure 6D through 8B may be maintained. In one embodiment, the proximity heads 106a and 106b (as well as any other proximity head described herein) may each be moved to between about 0.1 mm to about 10 mm from the wafer to initiate wafer processing operations. In a preferable embodiment, the proximity heads 106a and 106b (as well as any other proximity head described herein) may each be moved to between about 0.5 mm to about 4.5 mm from the

wafer to initiate wafer processing operations, and in more preferable embodiment, the proximity heads 106a and 106b (as well as any other proximity head described herein) may be moved to about 2 mm from the wafer to initiate wafer processing operations.

Figure 2B shows an alternate view of the wafer cleaning and drying system 100 in accordance with one embodiment of present invention. The system 100, in one embodiment, has the proximity head carrier assembly 104 that is configured to enable the proximity heads 106a and 106b to be moved from the center of the wafer towards the edge of the wafer. It should be appreciated that the proximity head carrier assembly 104 may be movable in any suitable manner that would enable movement of the proximity heads 106a and 106b to clean and/or dry the wafer as desired. In one embodiment, the proximity head carrier assembly 104 can be motorized to move the proximity head 106a and 106b from the center of the wafer to the edge of the wafer. It should be understood that although the wafer cleaning and drying system 100 is shown with the proximity heads 106a and 106b, that any suitable number of proximity heads may be utilized such as, for example, 1, 2, 3, 4, 5, 6, etc. The proximity heads 106a and/or 106b of the wafer cleaning and drying system 100 may also be any suitable size or shape as shown by, for example, any of the proximity heads as described herein. The different configurations described herein generate a fluid meniscus between the proximity head and the wafer. The fluid meniscus may be moved across the wafer to clean and dry the wafer by applying fluid to the wafer surface and removing the fluids from the surface. Therefore, the proximity heads 106a and 106b can have any numerous types of configurations as shown herein or other configurations that enable the processes described herein. It should also be appreciated that the system 100 may clean and dry one surface of the wafer or both the top surface and the bottom surface of the wafer.

In addition, besides cleaning or drying both the top and bottom surfaces and of the wafer, the system 100 may also be configured to clean one side of the wafer and dry another side of the wafer if desired by inputting and outputting different types of fluids. It should be appreciated that the system 100 may utilize the application of different chemicals top and bottom in the proximity heads 106a and 106b respectively depending on the operation desired. The proximity heads can be configured to clean and dry the bevel

edge of the wafer in addition to cleaning and/or drying the top and/or bottom of the wafer. This can be accomplished by moving the meniscus off the edge the wafer which cleans the bevel edge. It should also be understood that the proximity heads 106a and 106b may be the same type of apparatus or different types of proximity heads.

Figure 2C illustrates a side close-up view of the wafer cleaning and drying system 100 holding a wafer 108 in accordance with one embodiment of the present invention. The wafer 108 may be held and rotated by the rollers 102a, 102b, and 102c in any suitable orientation as long as the orientation enables a desired proximity head to be in close proximity to a portion of the wafer 108 that is to be cleaned or dried. In one embodiment, the roller 102b may be rotated by using a spindle 111, and the roller 102c may held and rotated by a roller arm 109. The roller 102a may also be rotated by its own spindle (as shown in Figure 3B. In one embodiment, the rollers 102a, 102b, and 102c can rotate in a clockwise direction to rotate the wafer 108 in a counterclockwise direction. It should be understood that the rollers may be rotated in either a clockwise or a counterclockwise direction depending on the wafer rotation desired. In one embodiment, the rotation imparted on the wafer 108 by the rollers 102a, 102b, and 102c serves to move a wafer area that has not been processed into close proximity to the proximity heads 106a and 106b. However, the rotation itself does not dry the wafer or move fluid on the wafer surfaces towards the edge of the wafer. Therefore, in an exemplary drying operation, the wet areas of the wafer would be presented to the proximity heads 106a and 106b through both the linear motion of the proximity heads 106a and 106b and through the rotation of the wafer 108. The drying or cleaning operation itself is conducted by at least one of the proximity heads. Consequently, in one embodiment, a dry area of the wafer 108 would expand from a center region to the edge region of the wafer 108 in a spiral movement as a drying operation progresses. In a preferable embodiment, the dry are of the wafer 108 would move around the wafer 108 and the wafer 108 would be dry in one rotation (if the length of the proximity heads 106a and 106b are at least a radius of the wafer 108) By changing the configuration of the system 100 and the orientation of and movement of the proximity head 106a and/or the proximity head 106b, the drying movement may be changed to accommodate nearly any suitable type of drying path.

It should be understood that the proximity heads 106a and 106b may be configured to have at least one of first source inlet configured to input deionized water (DIW) (also known as a DIW inlet), at least one of a second source inlet configured to input isopropyl alcohol (IPA) in vapor form (also known as IPA inlet), and at least one source outlet configured to output fluids from a region between the wafer and a particular proximity head by applying vacuum (also known as vacuum outlet). It should be appreciated that the vacuum utilized herein may also be suction. In addition, other types of solutions may be inputted into the first source inlet and the second source inlet such as, for example, cleaning solutions, ammonia, HF, etc. It should be appreciated that although IPA vapor is used in some of the exemplary embodiments, any other type of vapor may be utilized such as for example, nitrogen, any suitable alcohol vapor, organic compounds, etc. that may be miscible with water.

In one embodiment, the at least one IPA vapor inlet is adjacent to the at least one vacuum outlet which is in turn adjacent to the at least one DIW inlet to form an IPA-vacuum-DIW orientation. It should be appreciated that other types of orientations such as IPA-DIW-vacuum, DIW-vacuum-IPA, vacuum-IPA-DIW, etc. may be utilized depending on the wafer processes desired and what type of wafer cleaning and drying mechanism is sought to be enhanced. In a preferable embodiment, the IPA-vacuum-DIW orientation may be utilized to intelligently and powerfully generate, control, and move the meniscus located between a proximity head and a wafer to clean and dry wafers. The DIW inlets, the IPA vapor inlets, and the vacuum outlets may be arranged in any suitable manner if the above orientation is maintained. For example, in addition to the IPA vapor inlet, the vacuum outlet, and the DIW inlet, in an additional embodiment, there may be additional sets of IPA vapor outlets, DIW inlets and/or vacuum outlets depending on the configuration of the proximity head desired. Therefore, another embodiment may utilize an IPA-vacuum-DIW-DIW-vacuum-IPA or other exemplary embodiments with an IPA source inlet, vacuum source outlet, and DIW source inlet configurations are described herein with a preferable embodiment being described in reference to Figure 6D. It should be appreciated that the exact configuration of the IPA-vacuum-DIW orientation may be varied depending on the application. For example, the distance between the IPA input, vacuum, and DIW input locations may be varied so the distances are consistent or so the

distances are inconsistent. In addition, the distances between the IPA input, vacuum, and DIW output may differ in magnitude depending on the size, shape, and configuration of the proximity head 106a and the desired size of a process window as described in further detail in reference to Figure 10. In addition, as discussed in reference to Figure 10, the IPA-vacuum-DIW orientation is configured so a vacuum region substantially surrounds a DIW region and the IPA region substantially surrounds at least the trailing edge region of the vacuum region.

Figure 2D shows another side close-up view of the wafer cleaning and drying system 100 in accordance with one embodiment of the present invention. In this embodiment, the proximity heads 106a and 106b have been positioned in close proximity to a top surface 108a and a bottom surface 108b of the wafer 108 respectively by utilization of the proximity head carrier assembly 104. Once in this position, the proximity heads 106a and 106b may utilize the IPA and DIW source inlets and a vacuum source outlet(s) to generate wafer processing meniscuses in contact with the wafer 108 which are capable of removing fluids from a top surface 108a and a bottom surface 108b. The wafer processing meniscus may be generated in accordance with the descriptions in reference to Figures 6 through 9B where IPA vapor and DIW are inputted into the region between the wafer 108 and the proximity heads 106a and 106b. At substantially the same time the IPA and DIW is inputted, a vacuum may be applied in close proximity to the wafer surface to output the IPA vapor, the DIW, and the fluids that may be on a wafer surface. It should be appreciated that although IPA is utilized in the exemplary embodiment, any other suitable type of vapor may be utilized such as for example, nitrogen, any suitable alcohol vapor, organic compounds, hexanol, ethyl glycol, etc. that may be miscible with water. The portion of the DIW that is in the region between the proximity head and the wafer is the meniscus. It should be appreciated that as used herein, the term "output" can refer to the removal of fluid from a region between the wafer 108 and a particular proximity head, and the term "input" can be the introduction of fluid to the region between the wafer 108 and the particular proximity head.

In another exemplary embodiment, the proximity heads 106a and 106b may be moved in a manner so all parts of the wafer 108 are cleaned, dried, or both without the

wafer 108 being rotated. In such an embodiment, the proximity head carrier assembly 104 may be configured to enable movement of the either one or both of the proximity heads 106a and 106b to close proximity of any suitable region of the wafer 108. In one embodiment, of the proximity heads are smaller in length than a radius of the wafer, the proximity heads may be configured to move in a spiral manner from the center to the edge of the wafer 108 or vice versa. In a preferable embodiment, when the proximity heads are larger in length than a radius of the wafer, the proximity heads 106a and 106b may be moved over the entire surface of the wafer in one rotation. In another embodiment, the proximity heads 104a and 104b may be configured to move in a linear fashion back and forth across the wafer 108 so all parts of the wafer surfaces 108a and/or 108b may be processed. In yet another embodiment, configurations as discussed below in reference to Figure 5C through 5H may be utilized. Consequently, countless different configurations of the system 100 may be utilized in order to obtain an optimization of the wafer processing operation.

Figure 3A shows a top view illustrating the wafer cleaning and drying system 100 with dual proximity heads in accordance with one embodiment of the present invention. As described above in reference to Figures 2A to 2D, the upper arm 104a may be configured to move and hold the proximity head 106a in a position in close proximity over the wafer 108. The upper arm 104a may also be configured to move the proximity head 106a from a center portion of the wafer 108 towards the edge of the wafer 108 in a substantially linear fashion 113. Consequently, in one embodiment, as the wafer 108 moves as shown by rotation 112, the proximity head 106a is capable of removing a fluid film from the top surface 108a of the wafer 108 using a process described in further detail in reference to Figures 6 through 8. Therefore, the proximity head 106a may dry the wafer 108 in a substantially spiral path over the wafer 108. In another embodiment as shown in reference to Figure 3B, there may be a second proximity head located below the wafer 108 to remove a fluid film from the bottom surface 108b of the wafer 108.

Figure 3B illustrates a side view of the wafer cleaning and drying system 100 with dual proximity heads in accordance with one embodiment of the present invention. In this embodiment, the system 100 includes both the proximity head 106a capable of processing

a top surface of the wafer 108 and the proximity head 106b capable of processing a bottom surface of the wafer 108. In one embodiment, spindles 111a and 111b along with a roller arm 109 may rotate the rollers 102a, 102b, and 102c respectively. This rotation of the rollers 102a, 102b, and 102c may rotate the wafer 108 so substantially all surfaces of the wafer 108 may be presented to the proximity heads 106a and 106b for drying and/or cleaning. In one embodiment, while the wafer 108 is being rotated, the proximity heads 106a and 106b are brought to close proximity of the wafer surfaces 108a and 108b by the arms 104a and 104b respectively. Once the proximity heads 106a and 106b are brought into close proximity to the wafer 108, the wafer drying or cleaning may be begun. In operation, the proximity heads 106a and 106b may each remove fluids from the wafer 108 by applying IPA, deionized water and vacuum to the top surface and the bottom surface of the wafer 108 as described in reference to Figure 6.

In one embodiment, by using the proximity heads 106a and 106b, the system 100 may dry a 200 mm wafer in less than 45 seconds. In another embodiment, where the proximity heads 106a and 106b are at least a radius of the wafer in length, the drying time for a wafer may be less than 30 seconds. It should be understood that drying or cleaning time may be decreased by increasing the speed at which the proximity heads 106a and 106b travels from the center of the wafer 108 to the edge of the wafer 108. In another embodiment, the proximity heads 106a and 106b may be utilized with a faster wafer rotation to dry the wafer 108 in less time. In yet another embodiment, the rotation of the wafer 108 and the movement of the proximity heads 106a and 106b may be adjusted in conjunction to obtain an optimal drying/cleaning speed. In one embodiment, the proximity heads 106a and 106b may move linearly from a center region of the wafer 108 to the edge of the wafer 108 at between about 0 mm per second to about 50 mm per second.

Figure 4A shows a top view of a wafer cleaning and drying system 100-1 which includes multiple proximity heads for a particular surface of the wafer 108 in accordance with one embodiment of the present invention. In this embodiment, the system 100-1 includes an upper arm 104a-1 and an upper arm 104a-2. As shown in Figure 4B, the system 100-1 also may include lower arm 104b-1 and lower arm 104b-2 connected to

proximity heads 106b-1 and 106b-2 respectively. In the system 100-1, the proximity heads 106a-1 and 106a-2 (as well as 106b-1 and 106b-2 if top and bottom surface processing is being conducted) work in conjunction so, by having two proximity heads processing a particular surface of the wafer 108, drying time or cleaning time may be cut to about half of the time. Therefore, in operation, while the wafer 108 is rotated, the proximity heads 106a-1, 106a-2, 106b-1, and 106b-2 start processing the wafer 108 near the center of the wafer 108 and move outward toward the edge of the wafer 108 in a substantially linear fashion. In this way, as the rotation 112 of the wafer 108 brings all regions of the wafer 108 in proximity with the proximity heads so as to process all parts of the wafer 108. Therefore, with the linear movement of the proximity heads 106a-1, 106a-2, 106b-1, and 106b-2 and the rotational movement of the wafer 108, the wafer surface being dried moves in a spiral fashion from the center of the wafer 108 to the edge of the wafer 108.

In another embodiment, the proximity heads 106a-1 and 106b-1 may start processing the wafer 108 and after they have moved away from the center region of the wafer 108, the proximity heads 106a-2 and 106b-2 may be moved into place in the center region of the wafer 108 to augment in wafer processing operations. Therefore, the wafer processing time may be decreased significantly by using multiple proximity heads to process a particular wafer surface.

Figure 4B shows a side view of the wafer cleaning and drying system 100-1 which includes multiple proximity heads for a particular surface of the wafer 108 in accordance with one embodiment of the present invention. In this embodiment, the system 100-1 includes both the proximity heads 106a-1 and 106a-2 that are capable of processing the top surface 108a of the wafer 108, and proximity heads 106b-1 and 106b-2 capable of processing the bottom surface 108b of the wafer 108. As in the system 100, the spindles 111a and 111b along with a roller arm 109 may rotate the rollers 102a, 102b, and 102c respectively. This rotation of the rollers 102a, 102b, and 102c may rotate the wafer 108 so substantially all surfaces of the wafer 108 may brought in close proximity to the proximity heads 106a-1, 106a-2, 106b-1, and 106b-2 for wafer processing operations.

In operation, each of the proximity heads 106a-1, 106a-2, 106b-1, and 106b-2 may remove fluids from the wafer 108 by applying IPA, deionized water and vacuum to the top

surface and the bottom surface of the wafer 108 as shown, for example, in Figure 6 through 8. By having two proximity heads per wafer side, the wafer processing operation (i.e., cleaning and/or drying) may be accomplished in substantially less time. It should be appreciated that as with the wafer processing system described in reference to Figure 3A and 3B, the speed of the wafer rotation may be varied to any suitable speed as long as the configuration enables proper wafer processing. In one embodiment, the wafer processing time may be decreased when half a rotation of the wafer 108 is used to dry the entire wafer. In such an embodiment, the wafer processing speed may be about half of the processing speed when only one proximity head is utilized per wafer side.

Figure 5A shows a top view of a wafer cleaning and drying system 100-2 with a proximity head 106a-3 in a horizontal configuration which extends across a diameter of the wafer 108 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106a-3 is held by an upper arm 104a-3 that extends across a diameter of the wafer 108. In this embodiment, the proximity head 106a-3 may be moved into a cleaning/drying position by a vertical movement of the upper arm 104a-3 so the proximity head 106a-3 can be in a position that is in close proximity to the wafer 108. Once the proximity head 106a-3 is in close proximity to the wafer 108, the wafer processing operation of a top surface of the wafer 108 can take place.

Figure 5B shows a side view of a wafer cleaning and drying system 100-2 with the proximity heads 106a-3 and 106b-3 in a horizontal configuration which extends across a diameter of the wafer 108 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106a-3 and the proximity head 106b-3 both are elongated to be able to span the diameter of the wafer 108. In one embodiment, while the wafer 108 is being rotated, the proximity heads 106a-3 and 106b-3 are brought to close proximity of the wafer surfaces 108a and 108b by the top arm 104a and a bottom arm 106b-3 respectively. Because the proximity heads 106a-3 and 106b-3 extend across the wafer 108, only half of a full rotation may be needed to clean/dry the wafer 108.

Figure 5C shows a top view of a wafer cleaning and drying system 100-3 with the proximity heads 106a-3 and 106b-3 in a horizontal configuration which is configured to clean and/or dry the wafer 108 that is stationary in accordance with one embodiment of the

present invention. In this embodiment, the wafer 108 may be held stationary by any suitable type of wafer holding device such as, for example, an edge grip, fingers with edge attachments, etc. The proximity head carrier assembly 104''' is configured to be movable from one edge of the wafer 108 across the diameter of the wafer 108 to an edge on the other side of the wafer 108 after crossing the entire wafer diameter. In this fashion, the proximity head 106a-3 and/or the proximity head 106b-3 (as shown below in reference to Figure 5D) may move across the wafer following a path along a diameter of the wafer 108 from one edge to an opposite edge. It should be appreciated that the proximity heads 106a-3 and/or 106b-3 may be move from any suitable manner that would enable moving from one edge of the wafer 108 to another diametrically opposite edge. In one embodiment, the proximity head 106a-3 and/or the proximity head 106b-3 may move in directions 121 (e.g., top to bottom or bottom to top of Figure 5C). Therefore, the wafer 108 may stay stationary without any rotation or movement and the proximity heads 106a-3 and/or the proximity head 106b-3 may move into close proximity of the wafer and, through one pass over the wafer 108, clean/dry the top and/or bottom surface of the wafer 108.

Figure 5D shows a side view of a wafer cleaning and drying system 100-3 with the proximity heads 106a-3 and 106b-3 in a horizontal configuration which is configured to clean and/or dry the wafer 108 that is stationary in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106a-3 is in a horizontal position with the wafer 108 also in a horizontal position. By use of the proximity head 106a-3 and the proximity head 106b-3 that spans at least the diameter of the wafer 108, the wafer 108 may be cleaned and/or dried in one pass by moving proximity heads 106a-3 and 106b-3 in the direction 121 as discussed in reference to Figure 5C.

Figure 5E shows a side view of a wafer cleaning and drying system 100-4 with the proximity heads 106a-3 and 106b-3 in a vertical configuration enabled to clean and/or dry the wafer 108 that is stationary in accordance with one embodiment of the present invention. In this embodiment, the proximity heads 106a-3 and 106b-3 are in a vertical configuration, and the proximity heads 106a-3 and 106b-3 are configured to move either from left to right, or from right to left, beginning from a first edge of the wafer 108 to a

second edge of the wafer 108 that is diametrically opposite to the first edge. Therefore, in such as embodiment, the proximity head carrier assembly 104''' may move the proximity heads 104a-3 and 104b-3 in close proximity with the wafer 108 and also enable the movement of the proximity heads 104a-3 and 104b-3 across the wafer from one edge to another so the wafer 108 may be processed in one pass thereby decreasing the time to clean and/or dry the wafer 108.

Figure 5F shows an alternate side view of a wafer cleaning and drying system 100-4 that is shifted 90 degrees from the side view shown in Figure 5E in accordance with one embodiment of the present invention. It should be appreciated that the proximity head carrier assembly 104''' may be oriented in any suitable manner such as for example, having the proximity head carrier assembly 104''' rotated 180 degrees as compared with what is shown in Figure 5F.

Figure 5G shows a top view of a wafer cleaning and drying system 100-5 with a proximity head 106a-4 in a horizontal configuration which extends across a radius of the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106a-4 extends across less than a radius of a substrate being processed. In another embodiment, the proximity head 106a-4 may extend the radius of the substrate being processed. In a preferable embodiment, the proximity head 106a-4 extends over a radius of the wafer 108 so the proximity head may process both the center point of the wafer 108 as well as an edge of the wafer 108 so the proximity head 106a-4 can cover and process the center point of the wafer and the edge of the wafer. In this embodiment, the proximity head 106a-4 may be moved into a cleaning/drying position by a vertical movement of the upper arm 104a-4 so the proximity head 106a-4 can be in a position that is in close proximity to the wafer 108. Once the proximity head 106a-4 is in close proximity to the wafer 108, the wafer processing operation of a top surface of the wafer 108 can take place. Because, in one embodiment, the proximity head 106a-4 extends over the radius of the wafer, the wafer may be cleaned and/or dried in one rotation.

Figure 5H shows a side view of a wafer cleaning and drying system 100-5 with the proximity heads 106a-4 and 106b-4 in a horizontal configuration which extends across a radius of the wafer 108 in accordance with one embodiment of the present invention. In

this embodiment, the proximity head 106a-4 and the proximity head 106b-4 both are elongated to be able to extend over and beyond the radius of the wafer 108. As discussed in reference to Figure 5G, depending on the embodiment desired, the proximity head 106a-4 may extend less than a radius, exactly a radius, or greater than a radius of the wafer 108. In one embodiment, while the wafer 108 is being rotated, the proximity heads 106a-4 and 106b-4 are brought to close proximity of the wafer surfaces 108a and 108b by the top arm 104a and a bottom arm 106b-4 respectively. Because in one embodiment, the proximity heads 106a-4and 106b-4 extend across greater than the radius of the wafer 108, only a full rotation may be needed to clean/dry the wafer 108.

It should be understood that any of the systems 100, 100-1, 100-2, 100-3, 100-4, 100-5, and any suitable variant thereof, may be utilized as a cluster tool within a wafer processing system. A cluster tool is an apparatus that may be incorporated into a frame assembly (such as those discussed in further detail in reference to Figures 17 through 21 below with other wafer processing equipment so multiple wafers and/or multiple types of wafer processing may be conducted in one system.

Figure 6A shows a proximity head inlet/outlet orientation 117 that may be utilized to clean and dry the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the orientation 117 is a portion of a proximity head 106a where other source inlets 302 and 306 in addition to other source outlets 304 may be utilized in addition to the orientation 117 shown. The orientation 117 may include a source inlet 306 on a leading edge 109 with a source outlet 304 in between the source inlet 306 and the source outlet 302.

Figure 6B shows another proximity head inlet/outlet orientation 119 that may be utilized to clean and dry the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the orientation 119 is a portion of a proximity head 106a where other source inlets 302 and 306 in addition to other source outlets 304 may be utilized in addition to the orientation 119 shown. The orientation 119 may include a source outlet 304 on a leading edge 109 with a source inlet 302 in between the source outlet 304 and the source inlet 306.

Figure 6C shows a further proximity head inlet/outlet orientation 121 that may be utilized to clean and dry the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the orientation 121 is a portion of a proximity head 106a where other source inlets 302 and 306 in addition to other source outlets 304 may be utilized in addition to the orientation 119 shown. The orientation 119 may include a source inlet 306 on a leading edge 109 with a source inlet 302 in between the source outlet 304 and the source outlet 306.

Figure 6D illustrates a preferable embodiment of a wafer drying process that may be conducted by a proximity head 106a in accordance with one embodiment of the present invention. Although Figure 6 shows a top surface 108a being dried, it should be appreciated that the wafer drying process may be accomplished in substantially the same way for the bottom surface 108b of the wafer 108. In one embodiment, a source inlet 302 may be utilized to apply isopropyl alcohol (IPA) vapor toward a top surface 108a of the wafer 108, and a source inlet 306 may be utilized to apply deionized water (DIW) toward the top surface 108a of the wafer 108. In addition, a source outlet 304 may be utilized to apply vacuum to a region in close proximity to the wafer surface to remove fluid or vapor that may located on or near the top surface 108a. It should be appreciated that any suitable combination of source inlets and source outlets may be utilized as long as at least one combination exists where at least one of the source inlet 302 is adjacent to at least one of the source outlet 304 which is in turn adjacent to at least one of the source inlet 306. The IPA may be in any suitable form such as, for example, IPA vapor where IPA in vapor form is inputted through use of a N_2 gas. Moreover, although DIW is utilized herein, any other suitable fluid may be utilized that may enable or enhance the wafer processing such as, for example, water purified in other ways, cleaning fluids, etc. In one embodiment, an IPA inflow 310 is provided through the source inlet 302, a vacuum 312 may be applied through the source outlet 304 and DIW inflow 314 may be provided through the source inlet 306. Therefore, an embodiment of the IPA-vacuum-DIW orientation as described above in reference to Figure 2 is utilized. Consequently, if a fluid film resides on the wafer 108, a first fluid pressure may be applied to the wafer surface by the IPA inflow 310, a second fluid pressure may be applied to the wafer surface by the DIW inflow 314, and a third fluid

pressure may be applied by the vacuum 312 to remove the DIW, IPA and the fluid film on the wafer surface.

Therefore, in one embodiment, as the DIW inflow 314 and the IPA inflow 310 is applied toward a wafer surface, any fluid on the wafer surface is intermixed with the DIW inflow 314. At this time, the DIW inflow 314 that is applied toward the wafer surface encounters the IPA inflow 310. The IPA forms an interface 118 (also known as an IPA/DIW interface 118) with the DIW inflow 314 and along with the vacuum 312 assists in the removal of the DIW inflow 314 along with any other fluid from the surface of the wafer 108. In one embodiment, the IPA/DIW interface 118 reduces the surface of tension of the DIW. In operation, the DIW is applied toward the wafer surface and almost immediately removed along with fluid on the wafer surface by the vacuum applied by the source outlet 304. The DIW that is applied toward the wafer surface and for a moment resides in the region between a proximity head and the wafer surface along with any fluid on the wafer surface forms a meniscus 116 where the borders of the meniscus 116 are the IPA/DIW interfaces 118. Therefore, the meniscus 116 is a constant flow of fluid being applied toward the surface and being removed at substantially the same time with any fluid on the wafer surface. The nearly immediate removal of the DIW from the wafer surface prevents the formation of fluid droplets on the region of the wafer surface being dried thereby reducing the possibility of contamination drying on the wafer 108. The pressure (which is caused by the flow rate of the IPA) of the downward injection of IPA also helps contain the meniscus 116.

The flow rate of the IPA assists in causing a shift or a push of water flow out of the region between the proximity head and the wafer surface and into the source outlets 304 through which the fluids may be outputted from the proximity head. Therefore, as the IPA and the DIW is pulled into the source outlets 304, the boundary making up the IPA/DIW interface 118 is not a continuous boundary because gas (e.g., air) is being pulled into the source outlets 304 along with the fluids. In one embodiment, as the vacuum from the source outlet 304 pulls the DIW, IPA, and the fluid on the wafer surface, the flow into the source outlet 304 is discontinuous. This flow discontinuity is analogous to fluid and gas being pulled up through a straw when a vacuum is exerted on combination of fluid and

gas. Consequently, as the proximity head 106a moves, the meniscus moves along with the proximity head, and the region previously occupied by the meniscus has been dried due to the movement of the IPA/DIW interface 118. It should also be understood that the any suitable number of source inlets 302, source outlets 304 and source inlets 306 may be utilized depending on the configuration of the apparatus and the meniscus size and shape desired. In another embodiment, the liquid flow rates and the vacuum flow rates are such that the total liquid flow into the vacuum outlet is continuous, so no gas flows into the vacuum outlet.

It should be appreciated any suitable flow rate may be utilized for the IPA, DIW, and vacuum as long as the meniscus 116 can be maintained. In one embodiment, the flow rate of the DIW through a set of the source inlets 306 is between about 25 ml per minute to about 3,000 ml per minute. In a preferable embodiment, the flow rate of the DIW through the set of the source inlets 306 is about 400 ml per minute. It should be understood that the flow rate of fluids may vary depending on the size of the proximity head. In one embodiment a larger head may have a greater rate of fluid flow than smaller proximity heads. This may occur because larger proximity heads, in one embodiment, have more source inlets 302 and 306 and source outlets 304 More flow for larger head.

In one embodiment, the flow rate of the IPA vapor through a set of the source inlets 302 is between about 1 standard cubic feet per hour (SCFH) to about 100 SCFH. In a preferable embodiment, the IPA flow rate is between about 5 and 50 SCFM.

In one embodiment, the flow rate for the vacuum through a set of the source outlets 304 is between about 10 standard cubic feet per hour (SCFH) to about 1250 SCFH. In a preferable embodiment, the flow rate for a vacuum though the set of the source outlets 304 is about 350 SCFH. In an exemplary embodiment, a flow meter may be utilized to measure the flow rate of the IPA, DIW, and the vacuum.

Figure 6E shows another wafer drying process using another source inlet/outlet orientation that may be conducted by a proximity head 106a in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106a may be moved over the top surface 108a of the wafer 108 so the meniscus may be moved along the wafer surface 108a. The meniscus applies fluid to the wafer surface and removes fluid

from the wafer surface thereby cleaning and drying the wafer simultaneously. In this embodiment, the source inlet 306 applies a DIW flow 314 toward the wafer surface 108a, the source inlet 302 applies IPA flow 310 toward the wafer surface 108a, and the source outlet 312 removes fluid from the wafer surface 108a. It should be appreciated that in this embodiment as well as other embodiments of the proximity head 106a described herein, additional numbers and types of source inlets and source outlets may be used in conjunction with the orientation of the source inlets 302 and 306 and the source outlets 304 shown in Figure 6E. In addition, in this embodiment as well as other proximity head embodiments, by controlling the amount of flow of fluids onto the wafer surface 108a and by controlling the vacuum applied, the meniscus may be managed and controlled in any suitable manner. For example, in one embodiment, by increasing the DIW flow 314 and/or decreasing the vacuum 312, the outflow through the source outlet 304 may be nearly all DIW and the fluids being removed from the wafer surface 108a. In another embodiment, by decreasing the DIW flow 314 and/or increasing the vacuum 312, the outflow through the source outlet 304 may be substantially a combination of DIW and air as well as fluids being removed from the wafer surface 108a.

Figure 6F shows another source inlet and outlet orientation where an additional source outlet 307 may be utilized to input an additional fluid in accordance with one embodiment of the present invention. The orientation of inlets and outlets as shown in Figure 6E is the orientation described in further detail in reference to Figure 6D except the additional source outlet 307 is included adjacent to the source inlet 306 on a side opposite that of the source outlet 304. In such an embodiment, DIW may be inputted through the source inlet 306 while a different solution such as, for example, a cleaning solution may be inputted through the source inlet 307. Therefore, a cleaning solution flow 315 may be utilized to enhance cleaning of the wafer 108 while at substantially the same time drying the top surface 108a of the wafer 108.

Figure 7A illustrates a proximity head 106 performing a drying operation in accordance with one embodiment of the present invention. The proximity head 106, in one embodiment, moves while in close proximity to the top surface 108a of the wafer 108 to conduct a cleaning and/or drying operation. It should be appreciated that the proximity

head 106 may also be utilized to process (e.g., clean, dry, etc.) the bottom surface 108b of the wafer 108. In one embodiment, the wafer 108 is rotating so the proximity head 106 may be moved in a linear fashion along the head motion while fluid is removed from the top surface 108a. By applying the IPA 310 through the source inlet 302, the vacuum 312 through source outlet 304, and the deionized water 314 through the source inlet 306, the meniscus 116 as discussed in reference to Figure 6 may be generated.

Figure 7B shows a top view of a portion of a proximity head 106 in accordance with one embodiment of the present invention. In the top view of one embodiment, from left to right are a set of the source inlet 302, a set of the source outlet 304, a set of the source inlet 306, a set of the source outlet 304, and a set of the source inlet 302. Therefore, as IPA and DIW are inputted into the region between the proximity head 106 and the wafer 108, the vacuum removes the IPA and the DIW along with any fluid film that may reside on the wafer 108. The source inlets 302, the source inlets 306, and the source outlets 304 described herein may also be any suitable type of geometry such as for example, circular opening, square opening, etc. In one embodiment, the source inlets 302 and 306 and the source outlets 304 have circular openings.

Figure 7C illustrates a proximity head 106 with angled source inlets 302' performing a drying operation in accordance with one embodiment of the present invention. It should be appreciated that the source inlets 302' and 306 and the source outlet(s) 304 described herein may be angled in any suitable way to optimize the wafer cleaning and/or drying process. In one embodiment, the angled source inlets 302' that input IPA vapor onto the wafer 108 is angled toward the source inlets 306 such that the IPA vapor flow is directed to contain the meniscus 116.

Figure 7D illustrates a proximity head 106 with angled source inlets 302' and angled source outlets 304' performing a drying operation in accordance with one embodiment of the present invention. It should be appreciated that the source inlets 302' and 306 and the angled source outlet(s) 304' described herein may be angled in any suitable way to optimize the wafer cleaning and/or drying process.

In one embodiment, the angled source inlets 302' that input IPA vapor onto the wafer 108 is angled at an angle θ_{500} toward the source inlets 306 such that the IPA vapor

flow is directed to contain the meniscus 116. The angled source outlet 304' may, in one embodiment, be angled at an angle θ_{500} towards the meniscus 116. It should be appreciated that the angle θ_{500} and the angle θ_{502} may be any suitable angle that would optimize the management and control of the meniscus 116. In one embodiment, the angle θ_{500} is greater than 0 degrees and less than 90 degrees, and the angle θ_{502} is greater than 0 degrees and less than 90 degrees. In a preferable embodiment, the angle θ_{500} is about 15 degrees, and in another preferable embodiment, the angle angled at an angle θ_{502} is about 15 degrees. The angle θ_{500} and the angle θ_{502} adjusted in any suitable manner to optimize meniscus management. In one embodiment, the angle θ_{500} and the angle θ_{502} may be the same, and in another embodiment, the angle θ_{500} and the angle θ_{502} may be different. By angling the angled source inlet(s) 302' and/or angling the angled source outlet(s) 304', the border of the meniscus may be more clearly defined and therefore control the drying and/or cleaning the surface being processed.

Figure 8A illustrates a side view of the proximity heads 106 and 106b for use in a dual wafer surface cleaning and drying system in accordance with one embodiment of the present invention. In this embodiment, by usage of source inlets 302 and 306 to input IPA and DIW respectively along with the source outlet 304 to provide a vacuum, the meniscus 116 may be generated. In addition, on the side of the source inlet 306 opposite that of the source inlet 302, there may be a source outlet 304 to remove DIW and to keep the meniscus 116 intact. As discussed above, in one embodiment, the source inlets 302 and 306 may be utilized for IPA inflow 310 and DIW inflow 314 respectively while the source outlet 304 may be utilized to apply vacuum 312. It should be appreciated that any suitable configuration of source inlets 302, source outlets 304 and source inlets 306 may be utilized. For example, the proximity heads 106 and 106b may have a configuration of source inlets and source outlets like the configuration described above in reference to Figure 7A and 7B. In addition, in yet more embodiments, the proximity heads 106 and 106b may be of a configuration as shown below in reference to Figures 9 through 15. Any suitable surface coming into contact with the meniscus 116 may be dried by the movement of the meniscus 116 into and away from the surface.

Figure 8B shows the proximity heads 106 and 106b in a dual wafer surface cleaning and drying system in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106 processes the top surface 108a of the wafer 108, and the proximity head 106b processes the bottom surface of 108b of the wafer 108. By the inputting of the IPA and the DIW by the source inlets 302 and 306 respectively, and by use of the vacuum from the source outlet 304, the meniscus 116 may be formed between the proximity head 106 and the wafer 108 and between the proximity head 106b and the wafer 108. The proximity heads 106 and 106b, and therefore the meniscus 116, may be moved over the wet areas of the wafer surface in an manner so the entire wafer 108 can be dried.

Figure 9A illustrates a processing window 538-1 in accordance with one embodiment of the present invention. In one embodiment, the processing window 538-1 may include a plurality of source inlets 302 and 306 and also a plurality of source outlets 304. The processing window 538-1 is a region on a proximity head 106 (or any other proximity head referenced herein) that may generate and control the meniscus 116. Therefore, the processing window 538-1 may be a region that dries and/or cleans a wafer if the proximity head 106 is desired to be used in that manner. In one embodiment, the processing window 538-1 is a substantially rectangular shape. It should be appreciated that the size of the processing window 538-1 (or any other suitable processing window described herein) may be any suitable length and width (as seen from a top view).

Figure 9B illustrates a substantially circular processing window 538-2 in accordance with one embodiment of the present invention. In one embodiment, the processing window 538-2 may include a plurality of source inlets 302 and 306 and also a plurality of source outlets 304. The processing window 538-2 is a region on the proximity head 106 (or any other proximity head referenced herein) that may generate and control the meniscus 116. Therefore, the processing window 538-2 may be a region that dries and/or cleans a wafer if the proximity head 106 is desired to be used in that manner. In one embodiment, the processing window 538-2 is a substantially circular shape.

Figure 9C illustrates a processing window 538-3 in accordance with one embodiment of the present invention. In one embodiment, the processing window 538-3

may include a plurality of source inlets 302 and 306 and also a plurality of source outlets 304. The processing window 538-3 is a region on the proximity head 106 (or any other proximity head referenced herein) that may generate and control the meniscus 116. Therefore, the processing window 538-3 may be a region that dries and/or cleans a wafer if the proximity head 106 is desired to be used in that manner. In one embodiment, the processing window 538-3 is a substantially oval in shape.

Figure 9D illustrates a processing window 538-4 in accordance with one embodiment of the present invention. In one embodiment, the processing window 538-4 may include a plurality of source inlets 302 and 306 and also a plurality of source outlets 304. The processing window 538-4 is a region on the proximity head 106 (or any other proximity head referenced herein) that may generate and control the meniscus 116. Therefore, the processing window 538-4 may be a region that dries and/or cleans a wafer if the proximity head 106 is desired to be used in that manner. In one embodiment, the processing window 538-4 is a substantially square shape.

Figure 10A shows an exemplary process window 538-1 with the plurality of source inlets 302 and 306 as well as the plurality of source outlets 304 in accordance with one embodiment of the present invention. In one embodiment, the process window 538-1 in operation may be moved in direction 546 across a wafer during, for example, a wafer drying operation. In such an embodiment, a proximity head 106 may encounter fluids on a wafer surface on a leading edge region 548. The leading edge region 548 is an area of the proximity head 106 that, in a drying process, encounters fluids first. Conversely a trailing edge region 560 is an area of the proximity head 106 that encounters the area being processed last. As the proximity head 106 and the process window 538-1 included therein move across the wafer in the direction 546, the wet area of the wafer surface enter the process window 538-1 through the leading edge region 548. Then after processing of the wet region of the wafer surface by the meniscus that is generated and controllably maintained and managed by the process window 538-1, the wet region is dried and the dried region of the wafer (or substrate) leaves the process window 538-1 through a trailing edge region 560 of the proximity head 106. As discussed in reference to Figures 9A

through 9D, the process window 538-1 may be any suitable shape such as, for example, rectangular, square, circular, oval, semi-circular, etc.

Figure 10B shows processing regions 540, 542, and 544 of a proximity head 106 in accordance with one embodiment of the present invention. In one embodiment, the processing regions 540, 542, and 544 (the regions being shown by the broken lines) make up the processing window as discussed in reference to Figure 10A. It should be appreciated that the processing regions 540, 542, and 544 may be any suitable size and/or shape such as, for example, circular, ring, semi-circular, square, semi-square, free form, etc. as long as a stable and controllable fluid meniscus can be generated that can apply and remove fluids from a surface in an efficient manner. In one embodiment, the processing region 540 includes the plurality of source inlets 302, the processing region 542 (also known as a vacuum ring) includes the plurality of source outlets 304, and the processing region 544 includes the plurality of source inlets 306. In a preferable embodiment, the region 542 surrounds (or substantially surrounds) the region 544 with a ring of source outlets 304 (e.g., a vacuum ring). The region 540 substantially surrounds the region 544 but has an opening 541 where there are no source inlets 302 exist on a leading edge side of the process window 538-1.

Therefore, in operation, the proximity head 106 generates a fluid meniscus by application of IPA, DIW, and vacuum, in the regions 540, 542, and 544 in the process window 538 (as shown in Figure 10A). When the proximity head 106 is moving over the wafer surface in an exemplary drying operation, the wafer surface that moves through the opening 541 in the region 542 and contacts the meniscus 116 within the process window 538 is dried. The drying occurs because fluid that is on that portion of the wafer surface that contacts the meniscus 116 is removed as the meniscus moves over the surface. Therefore, wet surfaces of a wafer may enter the process window 538 through the opening 541 in the region 540 and by contacting the fluid meniscus may undergo a drying process.

It should be appreciated that although the plurality of source inlets 302, the plurality of source inlets 306, and the plurality of source outlets 304 are shown in this embodiment, other embodiments may be utilized where any suitable number of the source inlets 302, the source inlets 306, and the source outlets 304 may be utilized as long as the

configuration and number of the plurality of source inlets 302, the source inlets 306, and the source outlets 306 may generate a stable, controllable fluid meniscus that can dry a surface of a substrate. It should be understood that any suitable type of substrate such as, for example, a semiconductor wafer may be processed by the apparatuses and methodology described herein.

Figures 11 through 14 illustrate exemplary embodiments of the proximity head 106. It should be appreciated any of the different embodiments of the proximity head 106 described may be used as one or both of the proximity heads 106a and 106b described above in reference to Figures 2A through 5H. As shown by the exemplary figures that follow, the proximity head may be any suitable configuration or size that may enable the fluid removal process as described in Figures 6 to 10. Therefore, any, some, or all of the proximity heads described herein may be utilized in any suitable wafer cleaning and drying system such as, for example, the system 100 or a variant thereof as described in reference to Figures 2A to 2D. In addition, the proximity head may also have any suitable numbers or shapes of source outlets 304 and source inlets 302 and 306. It should be appreciated that the side of the proximity heads shown from a top view is the side that comes into close proximity with the wafer to conduct wafer processing. All of the proximity heads described in Figures 11 through 14 are manifolds that enable usage of the IPA-vacuum-DIW orientation in a process window or a variant thereof as described above in reference to Figures 2 through 10. The embodiments of the proximity head 106 as described below in reference to Figures 11 through 14 all have embodiments of the process window 538, and regions 540, 542, and 544 as described in reference to Figures 9A through 10B above. In addition, the proximity heads described herein may be utilized for either cleaning or drying operations depending on the fluid that is inputted and outputted from the source inlets 302 and 306, and the source outlets 304. In addition, the proximity heads described herein may have multiple inlet lines and multiple outlet lines with the ability to control the relative flow rates of liquid and/or vapor and/or gas through the outlets and inlets. It should be appreciated that every group of source inlets and source outlets can have independent control of the flows.

It should be appreciated that the size as well as the locations of the source inlets and outlets may be varied as long as the meniscus produced is stable. In one embodiment, the size of the openings to source inlets 302, source outlets 304, and source inlets 306 are between about 0.02 inch and about 0.25 inch in diameter. In a preferable embodiment, the size of the openings of the source inlets 306 and the source outlets 304 is about 0.06 inch, and the size of the openings of the source inlets 302 is about 0.03 inch.

In one embodiment the source inlets 302 and 306 in addition to the source outlets 304 are spaced about 0.03 inch and about 0.5 inch apart. In a preferable embodiment, the source inlets 306 are spaced 0.125 inch apart from each other and the source outlets 304 are spaced 0.125 inch apart and the source inlets 302 are spaced about 0.06 inch apart.

Additionally, the proximity heads may not necessarily be a "head" in configuration but may be any suitable configuration, shape, and/or size such as, for example, a manifold, a circular puck, a bar, a square, an oval puck, a tube, a plate etc., as long as the source inlets 302, and 306, and the source outlets 304 may be configured in a manner that would enable the generation of a controlled, stable, manageable fluid meniscus. In a preferable embodiment, the proximity head may be a type of manifold as described in reference to Figures 10A through 14C. The size of the proximity heads may be varied to any suitable size depending on the application desired. In one embodiment, the length (from a top view showing the process window) of the proximity heads may be between 1.0 inch to about 18.0 inches and the width (from a top view showing the process window) may be between about 0.5 to about 6.0 inches. Also when the proximity head may be optimized to process any suitable size of wafers such as, for example, 200mm wafers, 300, wafers, etc. The process windows of the proximity heads may be arranged in any suitable manner as long as such a configuration may generate a controlled stable and manageable fluid meniscus.

Figure 11A shows a top view of a proximity head 106-1 with a substantially rectangular shape in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106-1 includes three of the source inlets 302 which, in one embodiment, applies IPA to a surface of the wafer 108.

In this embodiment, the source inlets 302 are capable of applying IPA toward a wafer surface region, the source inlets 306 are capable of applying DIW toward the wafer surface region, and the source outlets 304 are capable of applying vacuum to a region in close proximity of a surface of the wafer 108. By the application of the vacuum, the IPA, DIW, and any other type of fluids that may reside on a wafer surface may be removed.

The proximity head 106-1 also includes ports 342a, 342b, and 342c that, in one embodiment, correspond to the source inlet 302, source outlet 304, and source inlet 306 respectively. By inputting or removing fluid through the ports 342a, 342b, and 342c, fluids may be inputted or outputted through the source inlet 302, the source outlet 304, and the source inlet 306. Although the ports 342a, 342b, and 342c correspond with the source inlet 302, the source outlet 304, and the source inlet 306 in this exemplary embodiment, it should be appreciated that the ports 342a, 342b, and 342c may supply or remove fluid from any suitable source inlet or source outlet depending on the configuration desired. Because of the configuration of the source inlets 302 and 306 with the source outlets 304, the meniscus 116 may be formed between the proximity head 106-1 and the wafer 108. The shape of the meniscus 116 may vary depending on the configuration and dimensions of the proximity head 106-1.

It should be appreciated that the ports 342a, 342b, and 342c for any of the proximity heads described herein may be any suitable orientation and dimension as long as a stable meniscus can be generated and maintained by the source inlets 302, source outlets 304, and source inlets 306. The embodiments of the ports 342a, 342b, and 342c described herein may be applicable to any of the proximity heads described herein. In one embodiment, the port size of the ports 342a, 342b, and 342c may be between about 0.03 inch and about 0.25 inch in diameter. In a preferable embodiment, the port size is about 0.06 inch to 0.18 inch in diameter. In one embodiment, the distance between the ports is between about 0.125 inch and about 1 inch apart. In a preferable embodiment, the distance between the ports is between about 0.25 inch and about 0.37 inch apart.

Figure 11B illustrates a side view of the proximity head 106-1 in accordance with one embodiment of present invention. The proximity head 106-1 includes the ports 342a, 342b, and 342c. In one embodiment, the ports 342a, 342b, and 342c feed source inlets

302, source outlets 304, and the source inlets 306 respectively. It should be understood that the ports may be any suitable number, size, or shape as long as the source inlets 302 and 306 as well as source outlets 304 may be utilized to generate, maintain, and manage the meniscus 116.

Figure 11C shows a rear view of the proximity head 106-1 in accordance with one embodiment of the present invention. The rear view of the proximity head 106-1, in one embodiment, corresponds to the leading edge 548 of the proximity head 106-1. It should be appreciated that the proximity head 106-1 is exemplary in nature and may be any suitable dimension as long as the source inlets 302 and 306 as well as the source outlet 304 are configured in a manner to enable cleaning and/or drying of the wafer 108 in the manner described herein. In one embodiment, the proximity head 106-1 includes the input ports 342c which may feed fluid to at least some of the source inlets 302a which run parallel to the input ports 342c shown in Figure 11C.

Figure 12A shows a proximity head 106-2 with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106-2 includes one row of source inlets 306 that is adjacent on both sides to rows of source outlets 304. One of the rows of source outlets 304 is adjacent to two rows of source inlets 302. Perpendicular to and at the ends of the rows described above are rows of source outlets 304.

Figure 12B shows a side view of the proximity head 106-2 with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106-2 includes ports 342a, 342b, and 342c on a side of the proximity head 106-2. The ports 342a, 342b, and 342c may be utilized to input and/or output fluids through the source inlets 302 and 306 and the source outlets 304. In one embodiment, the ports 342a, 342b, and 342c correspond to the source inlets 302, the source outlets 304, and the source inlets 306 respectively.

Figure 12C shows a back view of the proximity head 106-2 with a partial rectangular and partial circular shape in accordance with one embodiment of the present invention. The back side as shown by the rear view is where the back side is the square end of the proximity head 106-2.

Figure 13A shows a rectangular proximity head 106-3 in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106-3 includes a configuration of source inlets 302 and 306 and source outlets 304' that is similar to the proximity head 106-1 as discussed in reference to Figure 11A. The rectangular proximity head 106-3 includes the source outlets 304' that are larger in diameter than the source outlets 304. In any of the proximity heads described herein, the diameter of the source inlets 302 and 306 as well as the source outlets 304 may be altered so meniscus generation, maintenance, and management may be optimized. In this embodiment, the source inlets 302 are capable of applying IPA toward a wafer surface region, the source inlets 306 are capable of applying DIW toward the wafer surface region, and the source outlets 304 are capable of applying vacuum to a region in close proximity of a surface of the wafer 108. By the application of the vacuum, the IPA, DIW, and any other type of fluids that may reside on a wafer surface may be removed.

The proximity head 106-3 also includes ports 342a, 342b, and 342c that, in one embodiment, correspond to the source inlet 302, source outlet 304, and source inlet 306 respectively. By inputting or removing fluid through the ports 342a, 342b, and 342c, fluids may be inputted or outputted through the source inlet 302, the source outlet 304, and the source inlet 306. Although the ports 342a, 342b, and 342c correspond with the source inlet 302, the source outlet 304, and the source inlet 306 in this exemplary embodiment, it should be appreciated that the ports 342a, 342b, and 342c may supply or remove fluid from any suitable source inlet or source outlet depending on the configuration desired. Because of the configuration of the source inlets 302 and 306 with the source outlets 304, the meniscus 116 may be formed between the proximity head 106-1 and the wafer 108. The shape of the meniscus 116 may vary depending on the configuration and dimensions of the proximity head 106-1.

It should be appreciated that the ports 342a, 342b, and 342c for any of the proximity heads described herein may be any suitable orientation and dimension as long as a stable meniscus can be generated and maintained by the source inlets 302, source outlets 304, and source inlets 306. The embodiments of the ports 342a, 342b, and 342c described in relation to the proximity head 106-1 may be applicable to any of the proximity heads

described in reference to the other Figures. In one embodiment, the port size of the ports 342a, 342b, and 342c may be between about 0.03 inch and about 0.25 inch in diameter. In a preferable embodiment, the port size is about 0.06 inch to 0.18 inch in diameter. In one embodiment, the distance between the ports is between about 0.125 inch and about 1 inch apart. In a preferable embodiment, the distance between the ports is between about 0.25 inch and about 0.37 inch apart.

Figure 13B shows a rear view of the proximity head 106-3 in accordance with one embodiment of the present invention. The rear view of the proximity head 106-3, in one embodiment, corresponds to the leading edge 548 of the proximity head 106-3. It should be appreciated that the proximity head 106-3 is exemplary in nature and may be any suitable dimension as long as the source inlets 302 and 306 as well as the source outlet 304 are configured in a manner to enable cleaning and/or drying of the wafer 108 in the manner described herein. In one embodiment, the proximity head 106-3 includes the input ports 342c which may feed fluid to at least some of the source inlets 302a which run parallel to the input ports 342c shown in Figure 13A.

Figure 13C illustrates a side view of the proximity head 106-3 in accordance with one embodiment of present invention. The proximity head 106-3 includes the ports 342a, 342b, and 342c. In one embodiment, the ports 342a, 342b, and 342c feed source inlets 302, source outlets 304, and the source inlets 306 respectively. It should be understood that the ports may be any suitable number, size, or shape as long as the source inlets 302 and 306 as well as source outlets 304 may be utilized to generate, maintain, and manage the meniscus 116.

Figure 14A shows a rectangular proximity head 106-4 in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106-4 includes a configuration of source inlets 302 and 306 and source outlets 304' that is similar to the proximity head 106-3 as discussed in reference to Figure 13A. The rectangular proximity head 106-3 includes the source outlets 304' that are larger in diameter than the source outlets 304. In any of the proximity heads described herein, the diameter of the source inlets 302 and 306 as well as the source outlets 304 may be altered so meniscus generation, maintenance, and management may be optimized. In one embodiment, the

source outlets 304' are located closer to the source inlets 302 than the configuration discussed in reference to Figure 13A. With this type of configuration, a smaller meniscus may be generated. The region spanned by the source inlets 302, 306 and source outlets 304' (or also source outlets 304 as described in reference to Figure 11A) may be any suitable size and/or shape. In one embodiment, the process window may be between about 0.03 to about 9.0 square inches. In a preferable embodiment, the process window may be about 0.75 inch. Therefore, by adjusting the region of the In this embodiment, the source inlets 302 are capable of applying IPA toward a wafer surface region, the source inlets 306 are capable of applying DIW toward the wafer surface region, and the source outlets 304 are capable of applying vacuum to a region in close proximity of a surface of the wafer 108. By the application of the vacuum, the IPA, DIW, and any other type of fluids that may reside on a wafer surface may be removed.

The proximity head 106-3 also includes ports 342a, 342b, and 342c that, in one embodiment, correspond to the source inlet 302, source outlet 304, and source inlet 306 respectively. By inputting or removing fluid through the ports 342a, 342b, and 342c, fluids may be inputted or outputted through the source inlet 302, the source outlet 304, and the source inlet 306. Although the ports 342a, 342b, and 342c correspond with the source inlet 302, the source outlet 304, and the source inlet 306 in this exemplary embodiment, it should be appreciated that the ports 342a, 342b, and 342c may supply or remove fluid from any suitable source inlet or source outlet depending on the configuration desired. Because of the configuration of the source inlets 302 and 306 with the source outlets 304, the meniscus 116 may be formed by the process window between the proximity head 106-1 and the wafer 108. The shape of the meniscus 116 may correspond with the shape of the process window and therefore the size and shape of the meniscus 116 may be varied depending on the configuration and dimensions of the regions of source inlets 302 and 306 and regions of the source outlets 304.

Figure 14B shows a rear view of the rectangular proximity head 106-4 in accordance with one embodiment of the present invention. The rear view of the proximity head 106-4, in one embodiment, corresponds to the leading edge 548 of the proximity head 106-4. It should be appreciated that the proximity head 106-4 is exemplary in nature

and may be any suitable dimension as long as the source inlets 302 and 306 as well as the source outlet 304 are configured in a manner to enable cleaning and/or drying of the wafer 108 in the manner described herein. In one embodiment, the proximity head 106-4 includes the input ports 342c which may feed fluid to at least some of the source inlets 302a which run parallel to the input ports 342c shown in Figure 13A.

Figure 14C illustrates a side view of the rectangular proximity head 106-4 in accordance with one embodiment of present invention. The proximity head 106-4 includes the ports 342a, 342b, and 342c. In one embodiment, the ports 342a, 342b, and 342c feed source inlets 302, source outlets 304, and the source inlets 306 respectively. It should be understood that the ports may be any suitable number, size, or shape as long as the source inlets 302 and 306 as well as source outlets 304 may be utilized to generate, maintain, and manage the meniscus 116.

Figure 15A shows a proximity head 106 in operation according to one embodiment of the present invention. It should be appreciated that the flow rate of the DIW and the IPA, the magnitude of the vacuum, and rotation/movement of the wafer being processed may be varied in any suitable manner to provide optimal fluid meniscus controllability and management to generate enhanced wafer processing. The proximity head 106, in one exemplary embodiment, is utilized in a configuration as described in reference to Figure 2A. As shown in reference to Figures 15A through 15F, the wafer is a clear material so fluid meniscus dynamics can be seen with different flow rates, vacuum rates, and wafer rotations. The flow rate of DIW and IPA as well as the vacuum and rotation of the wafer may be varied depending on the conditions encountered during drying. In Figure 15A, the meniscus has been formed by input of DIW and vacuum without any IPA flow. Without the IPA flow, the meniscus has an uneven boundary. In this embodiment, the wafer rotation is zero and the DIW flow rate is 500 ml/min.

Figure 15B illustrates the proximity head 106 as described in Figure 15A with IPA input in accordance with one embodiment of the present invention. In this embodiment, the DIW flow rate is 500 ml/min and the IPA flow rate is 12 ml/min with the rotation of the wafer being zero. As shown by Figure 15B, the usage of IPA flow has made the

boundary of the meniscus more even. Therefore, the fluid meniscus is more stable and controllable.

Figure 15C shows the proximity head 106 as described in Figure 15B, but with the IPA flow increased to 24 ml/min in accordance with one embodiment of the present invention. The rotation has been kept at zero and the flow rate of the DIW is 500 ml/min. When the IPA flow rate is too high, the fluid meniscus becomes deformed and less controllable.

Figure 15D shows the proximity head 106 where the fluid meniscus is shown where the wafer is being rotated in accordance with one embodiment of the present invention. In this embodiment, the rotation of the wafer is 10 rotations per minute. The flow rate of the DIW is 500 ml/min while the flow rate of the IPA is 12 SCFH. The magnitude of the vacuum is about 30 in Hg@ 80 PSIG. When the wafer is rotated, the fluid meniscus becomes less stable due to the added wafer dynamics as compared with Figure 15C which shows the same DIW and IPA flow rate but without wafer rotation. Figure 15E shows the proximity head 106 where the fluid meniscus is shown where the wafer is being rotated faster than the rotation shown in Figure 15D in accordance with one embodiment of the present invention. In this embodiment, the rotation of the wafer is 15 rotations per minute. The flow rate of the DIW is 500 ml/min while the flow rate of the IPA is 12 SCFH. The magnitude of the vacuum is about 30 in HG@ 80 PSIG. When the wafer is rotated faster, the fluid meniscus has a more uneven boundary as compared to the fluid meniscus discussed in reference to Figure 15D due to the added wafer dynamics as compared.

Figure 15F shows the proximity head 106 where the IPA flow has been increased as compared to the IPA flow of Figure 15D in accordance with one embodiment of the present invention. In this embodiment, the variables such as the DIW flow rate, rate of wafer rotation, and vacuum magnitude are the same as that described in reference to Figure 15D. In this embodiment, the IPA flow rate was increased to 24 SCFH. With the IPA flow rate increased, the IPA holds the fluid meniscus along the border to generate a highly controllable and manageable fluid meniscus. Therefore, even with wafer rotation, the fluid meniscus looks stable with a consistent border that substantially corresponds to

the region with the plurality of source inlets 302 and the region with the plurality of source outlets 304. Therefore, a stable and highly controllable, manageable, and maneuverable fluid meniscus is formed inside of the process window so, in an exemplary drying process, fluid that the proximity head 106 may encounter on a wafer surface is removed thereby quickly and efficiently drying the wafer surface.

Figure 16A shows a top view of a cleaning/drying system 602 in accordance with one embodiment of the present invention. It should be appreciated that any of the embodiments of the drying system 100 (e.g., cleaning systems 100-1, 100-2, 100-3, 100-4, and 100-5) described herein with the any of the embodiments of the proximity head 106 described in Figures 2A to 15F herein may be utilized in conjunction with other wafer processing technologies to generate an integrated system such as, for example, those described in Figure 16A through 20 below. In one embodiment, the cleaning and drying system 100 may be incorporated into a 2300 Brush Box Assembly manufactured by Lam Research of Fremont, California.

In one embodiment, the cleaning/drying system 602 is the cleaning and drying system 100-5 described above in reference to Figures 5G and 5H with a brush core 604 and a spray manifold 606. In such an embodiment, when one of the cleaning and drying systems 100 are utilized in conjunction with a different wafer processing apparatus, the cleaning and drying systems (or components therein) may also be known as a wafer drying insert. It should be understood that the brush may be made out of any suitable material that may effectively clean a substrate such as, for example, polyvinyl alcohol (PVA), rubber, urethane, etc. In one embodiment, a brush such, as for example a polyvinyl alcohol (PVA) brush may be applied over the brush core 604. The brush core 604 may be any suitable brush core configuration such as, for example, those known to those skilled in the art. Therefore, when the brush core 604 rotates, the brush on the brush core 604 may be applied to the wafer 102 to clean the surface of the wafer after wafer processing such as, for example, etching, planarization, etc.

In one embodiment, after the wafer 102 is cleaned by the brush, the wafer 102 does not have to be taken out of the cleaning/drying 602 (also known as a cleaning/drying module) for drying. Therefore, after wafer cleaning, the wafer 102 may be dried as

discussed above in reference to Figures 2A through 15C above. In this fashion, time may be saved by having two wafer process operation in one module and chances for contamination are reduced because the wafer 102 does not have to be taken to a different module for cleaning.

Figure 16B shows an alternative view of the cleaning/drying system 602 in accordance with one embodiment of the present invention. The cleaning/drying system 602 may be a module(s) (e.g., cluster tool) in a variety of wafer processing systems as discussed below in reference to Figure 17 though 21. By having both a cleaning system and a drying system in one module, space may be saved and the wafer processing system may be made smaller and more compact while retaining substantially the same functionality.

Figure 17 illustrates a wafer processing system 700 with front end frame assembly 705 with a drying module 704 in accordance with one embodiment of the present invention. The drying module 704 may be any of the systems 100, 100-1, 100-2, 100-3, 100-4, 100-5, and any suitable variant thereof. It should be appreciated that any suitable number of drying modules 704 such as, for example, 1,2, 3, 4, 5, 6, 7, 8, 9, 10, etc. may be connected to the front end frame assembly 705 to generate the wafer processing system 700 with varying levels of wafer processing capabilities. It should also be understood that any other types of wafer processing tools may be connected to the front end frame assembly 705 such as, for example, a planarization tool/module, etching tool/module, cleaning tool/module, etc.

In one embodiment, the wafer processing system 700 includes 6 drying modules 704 and also has a robot 712 that may feed and remove wafers into and out of the drying modules 704. The robot 712 may also be configured to feed and remove wafers into and out of the front end loaders 710. It should be understood that any suitable number and types of robots 712 may be utilized as well as any suitable number and types of front end loaders 710. In one embodiment, the front end loaders 710 may receive a cartridge full of wafers which require processing by the wafer processing system 700.

Figure 18 shows a wafer processing system 800 which has multiple wafer processing tools in accordance with one embodiment of the present invention. In one

embodiment, the wafer processing system 800 includes an etching module 722, the drying module 704, the front end loader 710, and the robot 712 located on a frame assembly 720. The wafer processing system 700 as with the wafer processing system 800 may have any suitable number and any suitable types of modules/tools such as, CMP modules, megasonic processing modules, cleaning modules, and etching modules. Therefore an apparatus such as, for example, the wafer processing system 800 with different substrate/wafer processing modules may, in one embodiment, be called a cluster architecture system. In one embodiment, a drying system as described herein may be an integrated drying system when integrated with other modules to form the cluster architecture system. In an alternative embodiment, the wafer processing system 800 may have the etching module 722, the drying module 704, and a cleaning module. In one embodiment, the wafer processing system 700 may include three of the etching modules 622, and 6 of the drying modules 704. When multiple wafer processing occurs, this may be known as cluster processing. It should also be appreciated that any or all of the drying modules 704 may be replaced with a module containing the cleaning/drying system 602 so both cleaning and drying may be accomplished in the same module.

Figure 19 shows a wafer processing system 800' without the etching module 722 in accordance with one embodiment of the present invention. In one embodiment, the wafer processing system 800 has the frame 720 containing a plurality of the drying modules 704. The wafer processing system 800' may contain any suitable number of drying modules 704. In one embodiment, the wafer processing system 800' includes 8 of the drying modules 704. The wafer 102 is shown being loaded into the wafer processing system 800 through use of the front end loader 710. The robot 712 may take the wafer from the front end loader 710 and load the wafer 102 into any one of the plurality of drying modules 704. In this embodiment, the etching module 722 shown above in reference to Figure 18 has been removed to generate space to add more drying modules 704. In addition, the drying modules 704 may include the cleaning and drying system 602 described in further detail in reference to Figure 16A. In this way both drying and cleaning may be accomplished within one module.

Figure 20 illustrates a wafer processing system 800" which includes a drying module 704 and a cleaning module 850 in accordance with one embodiment of the present invention. In one embodiment, the wafer processing system 800" can include a separate cleaning module such as, for example, the cleaning module 850. It should be appreciated that any suitable number and/or types of cleaning apparatuses may be utilized within the wafer processing system 800", such as a brush box (or wafer brush scrubbing units), megasonic cleaning device, etc. In one embodiment, the cleaning module 850 may be a brush box. The brush box may be any suitable type of brush box that can effectively clean wafers such as known to those skilled in the art.

In yet another embodiment, the wafer processing system 800" may have a cleaning module 850 that is a megasonic module. In another embodiment, the megasonic module may conduct other types of processing besides cleaning. Any suitable megasonic processing device may be utilized as a megasonic module such as, for example, those described in U.S. Patent Application No. 10/259,023 entitled "MEGASONIC SUBSTRATE PROCESSING MODULE". The aforementioned patent application is hereby incorporated by reference. Therefore, by having various types of modules or wafer processing devices interconnected, wafer processing systems may be generated that have the capability to utilized multiple wafer processing methods.

Figure 21 shows a block diagram of a wafer processing system 900 in accordance with one embodiment of the present invention. In one embodiment, the system 900 includes a cleaning system 902, a chemical mechanical planarization (CMP) system 904, a megasonic system 906, and an etching system 908 with a deposition system. The system 900 also includes a robotics 912 that can transport substrates to and from each of the systems 902, 904, 906, 908, and 910. Therefore, the system 900 may include all of the major wafer processing tools. It should be understood that the system 900 can include one, some, or all of the systems 902, 904, 906, 908, and 910. It should also be appreciated that the system 900 can include any suitable number of any of the systems 902, 904, 906, 908, and 910 as well as other types of wafer processing systems known to those skilled in the art. Therefore, the system 900 has great flexibility in wafer processing abilities depending on the desires of a manufacturer or user.

The cleaning system 902 may be any suitable cleaning system such as, for example, brush box(es), spin, rinse, and dry (SRD) apparatus(es), etc. Any suitable type of brush box or SRD apparatuses may be utilized in the system 900. The CMP system 904 may be any suitable type of CMP apparatus such as those utilizing, for example, a table, one or more belts, etc. The megasonic system may be one as described above in reference to the megasonic processing device as described in further detail in reference to Figure 20. The etching system 908 may be any type of substrate etching device such as, for example, one that includes a robot that can obtain a wafer through a load lock and process the wafer in any number of process modules where etching can take place. A deposition system can optionally be utilized along with the etching system 908.

The drying system 910 may be any drying system described herein that utilize any of the different embodiments of the proximity head 106 as described above in reference to Figures 2A through 14C. Therefore, the drying system may be the system 100, 100-1, 100-2, 100-3, 100-4 or any variant thereof. Therefore, the system 900 may process the wafer 102 in any suitable number ways and dry the wafer 102 in a highly efficient and cost effective manner by usage of the drying system 910 of the present invention. Therefore, the drying system 910 may lower of wafer production costs and raise wafer yields.

Figures 22A through 25B show exemplary embodiments where a wafer that is oriented vertically may be processed by at least one proximity head where by either movement of the wafer and/or movement of the at least one proximity head, the wafer surface may be processed vertically from top to bottom. It should appreciated that wafer processing as described herein may include cleaning, drying, rinsing, etc. The vertical processing of the wafer can enhance control of the meniscus and reduce random fluid movement on the wafer during wafer processing. Consequently, by use of vertical wafer processing by the proximity head(s) (also known as manifold), wafer processing such as, for example, cleaning, rinsing, and/or drying may be accomplished in an efficient manner. It should be appreciated that the proximity head/manifold may be any suitable configuration or size as long as the proximity head/manifold structure is consistent with the methods and apparatus described herein. In a preferable embodiment, to achieve process uniformity, resident time of the meniscus on the wafer surface is uniform

throughout the wafer. Therefore, scanning direction and speed may be controlled so the meniscus area is scanned evenly over the wafer.

Figure 22A illustrates a proximity head 106a beginning a wafer processing operation where the wafer 108 is scanned vertically in accordance with one embodiment of the present invention. In one embodiment, the wafer 108 is oriented in a vertical manner so a top portion 108c of the wafer 108 is presented for scanning to the proximity head 106a. In such an orientation, the surface of the wafer being processed is substantially parallel to a processing window 538 of the proximity head 106a. It should be appreciated that the wafer 108 may be held in place or moved depending on the configuration of the wafer processing system. In one embodiment, as discussed in further detail in reference to Figure 23A, the wafer 108 is held into place and the proximity head is moved from a top to bottom scanning motion, where a top portion 108c of the wafer 108 is scanned before a bottom portion 108d of the wafer 108. In such an embodiment, the wafer 108 is positioned in a substantially vertical orientation. The position of the wafer 108 with respect to the y-axis can therefore be in any suitable angle as long as the top portion 108c of the wafer 108 is located higher along the y-axis than the bottom portion 108d of the wafer 108. In a preferable embodiment, the wafer 108 is positioned to be vertical along the y-axis. Therefore, in such an embodiment, the proximity head 106a may move vertically in a downward fashion and process the wafer surface from top to bottom.

In another embodiment, the proximity head 106a may be held stationary and the wafer 108 may be moved in a manner such that the wafer surface is processed in a vertical fashion where the top portion 108c of the wafer 108 is scanned before the bottom portion 108d of the wafer 108. It should be appreciated that any suitable device or apparatus may be used to move the proximity head 106a vertically so as to scan the surface of the wafer 108. In one embodiment, the proximity head 106a may be attached to an arm that is then attached to a mechanical device to move the proximity head 106a in a vertical manner. In another embodiment, the proximity head 106a may be directly attached to a mechanical device or apparatus that can facilitate movement of the proximity head 106a close to the surface of the wafer 108 and to move the proximity head 106 from the top portion 108c of the wafer 108 to the bottom portion 108d of the wafer 108.

It should also be appreciated that a proximity head 106b (not visible in Figure 22A but shown as an exemplary embodiment in Figure 22F and 22G) may be used along with the proximity head 106a to process both wafer surfaces on the two sides of the wafer 108. Therefore, the proximity heads 106a and 106b may be utilized, where one of the proximity heads may process one side of the wafer 108 and the other proximity head may process the other side of the wafer 108. The proximity heads 106a and 106b may be any suitable proximity head described herein. In a preferable embodiment, two proximity heads 106a and 106b may be oriented so that the processing windows face each other. The processing windows of the two proximity heads may then be oriented in close proximity to each other. In such an embodiment, the space between the processing windows would be large enough so as to be greater than the thickness of the wafer 108. Therefore, when a meniscus is formed between the two processing windows, the proximity heads 106a and 106b may be moved down from above the wafer 108. It should be appreciated that the proximity heads 106a and 106b (or any other proximity heads described herein) may be any suitable distance away from the wafer 108 as long as a stable controllable meniscus may be formed on the surface being processed. In one embodiment, the proximity heads 106a and 106b are about 0.1 mm to about 3 mm away from the respective surfaces being processed. In another embodiment, the proximity heads 106a and 106b are about 1 mm to about 2 mm away from the respective surfaces being processed, and in a preferable embodiment, the proximity heads 106a and 106b are about 1.5 mm away from the respective surfaces being processed. As the proximity head 106a and 106b move downward, the meniscus may contact the a top edge of the wafer 108 and one processing window would form a meniscus with one surface of the wafer 108 and the other processing windows would form a meniscus with the other surface of the wafer 108.

It should also be appreciated that the wafer processing operation could be started where the proximity heads 106a and 106b starts by initially producing the meniscus on the wafer instead of moving the meniscus onto the wafer 108 from above the top portion 108a.

Figure 22B illustrates a wafer processing continuing from Figure 22A where the proximity head 106a has started scanning the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the top surface of the wafer

108 is positioned in a substantially vertical orientation so the top surface of the wafer 108 is visible when view along a horizontal axis. As the proximity head 106a comes into close proximity of the wafer 108, the meniscus 116 is formed between the process window 538 of the proximity head 106a and the wafer surface being processed. In one embodiment, the proximity head 106a is configured to dry the wafer 108. In such an embodiment, the process window 538 intelligently controls and manages the meniscus 116 so drying takes place as the meniscus 116 moves from a top portion 108c of the wafer 108 to the bottom portion 108d of the wafer 108. Therefore, as the drying process takes place, the dried portion of the wafer 108 will become larger in a top to bottom direction. The generation of the meniscus is described in further detail above.

By processing the wafer 108 in a vertical orientation from top to bottom, the meniscus 116 may be optimally controlled by limiting the forces acting on the meniscus 116. In such a vertical orientation, only vertical forces exerted by gravity need be accounted for in the generation of a controlled and manageable meniscus. In addition, by scanning the proximity head 106 in a downward manner from the top portion 108c of the vertically oriented wafer 108, the region of the wafer 108 that has already been dried may be kept dried in an optimal manner. This may occur because the fluids or moisture in the wet regions of the wafer 108 not yet processed would not move up against gravity into the already dried regions.

Figure 22C shows a continuation of a wafer processing operation from Figure 22B in accordance with one embodiment of the present invention. In Figure 22C, the proximity head 106 has almost halfway (and processed about a semi-circle of the wafer 108) between the top portion 108c and the bottom portion 108d of the wafer 108.

Figure 22D illustrates the wafer processing operation continued from Figure 22C in accordance with one embodiment of the present invention. In Figure 22D, the proximity head 106a has almost finished scanning the wafer surface. In one embodiment, when both the proximity head 106a and 106b are processing the respective sides of the wafer 108, as portions of the meniscus 116 on each side finish processing and are no longer in contact with the wafer 108, the meniscuses on both sides of the wafer come into contact and become one meniscus.

Figure 22E shows the wafer processing operation continued from Figure 22D in accordance with one embodiment of the present invention. As shown in Figure 22E, the proximity head 106a (and 106b if a dual proximity head device is being utilized), has finished processing the wafer 108.

Figure 22F shows a side view of the proximity heads 106a and 106b situated over the top portion of the vertically positioned wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the proximity heads 106b and 106a may form the meniscus 116 as described above. The proximity heads 106a and 106b may be moved substantially together downward to process the wafer as described in further detail in reference to Figure 22G.

Figure 22G illustrates a side view of the proximity heads 106a and 106b during processing of dual surfaces of the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, as the proximity heads 106a and 106b move downward from above the wafer 108. As the meniscus 116 contacts the wafer 108, the proximity head 106a forms a meniscus 116a with the wafer 108 and the proximity head 106b forms a meniscus 116b with the wafer 108. Therefore, the proximity head 106a may process one side of the wafer 108 and the proximity head 106b may process the other side of the wafer. As discussed above, it should be understood that the proximity heads 106a and 106b may be moved downward, or the wafer 108 may be moved upward, or the proximity heads 106a and 106b may be moved downward while the wafer 108 is moved upward. Consequently, the scanning of the wafer 108 may take place using any suitable movement as long as the proximity heads 106a and 106b are moved in a downward movement relative to the wafer 108. By using this relative downward scanning motion, the drying may take place from the top portion 108a of the wafer 108 to the bottom portion 108b of the wafer 108.

Although Figures 22A to 22G shows the proximity head 106a moving from off the edge of the wafer 108 across the diameter to leave the edge of the wafer 108, other embodiments may be utilized where the proximity head 106a hovers over the wafer 108 near a top edge of the wafer 108 and moves toward the surface of the wafer 108. Once in close proximity to the wafer surface, the meniscus is formed and the meniscus is scanned

down along a diameter of the wafer 108. In yet another embodiment, the proximity head may process only a portion of the wafer surface.

Figure 23A shows a wafer processing system where the wafer is held stationary in accordance with one embodiment of the present invention. In one embodiment, the wafer 108 is held in place by holders 600. It should be appreciated that the holders 600 may be any suitable type of device or apparatus that can hold the wafer 108 and still enable the scanning of the wafer surface by the proximity head 106 such as, for example, edge grip, fingers with edge attachments, etc. In this embodiment, the proximity head 106 may be held and moved by a proximity head carrier 602. It should be appreciated that the proximity head carrier 602 may be any suitable type of apparatus or device that can move the proximity head 106 from above the wafer 108 and scan the proximity head 106 in a downward manner while keeping the proximity head 106 in close proximity to the wafer surface. In one embodiment, the proximity head carrier 602 may be similar to the proximity head carrier assembly as shown Figure 2A except that the wafer is oriented vertically and the proximity head carrier is configured to move from top to bottom in a vertical manner.

Figure 23B shows a wafer processing system where the proximity head carrier 602' may be held in place or moved in accordance with one embodiment of the present invention. In one embodiment, the wafer 108 may be held by edge gripper 604 and moved upward. By this upward motion, the wafer 108 may be scanned by the proximity head 106 in a relative downward manner where the proximity head 106 starts scanning the surface of the wafer 108 in the top portion and moves downward. In one embodiment, the proximity head carrier 602' may be kept still and the relative downward scan may be accomplished by the wafer being moved upward while scanning is taking place. In another embodiment, the wafer 108 may be moved upward and the proximity head carrier 602' may be moved downward. Therefore, the relative downward scan may be accomplished in one of many different variations of wafer holder motions and proximity head carrier motions.

In a preferable embodiment as shown in the bottom portion of Figure 23B, after the proximity head 106 has scanned over a majority of the wafer 108 and reaches the edge

gripper 604, the holders 600, such as described in reference to Figure 23A, may grip the wafer 108 and move it upward to complete the wafer processing. Once the holders 600 grab onto the wafer 108, the edge gripper 604 may release the wafer 108. Then another wafer may be moved into position for wafer processing operations by the proximity head 106.

Figure 23C shows a wafer processing system where the proximity head extends about a radius of the wafer 108 in accordance with one embodiment of the present invention. In one embodiment, the wafer processing system may utilize a proximity head that is capable of producing a meniscus that may cover at least a radius of the wafer 108. In this embodiment, the proximity head 106 may scan a wafer surface from a top portion 108c to a bottom portion 108d of the wafer 108. In another embodiment, two proximity heads 106 may be utilized where one semi-circle of the wafer surface is processed by one of the proximity heads 106 while the other semi-circle of the wafer surface is processed by the other of the proximity heads 106.

Figure 23D shows a wafer processing system where the proximity head 106 moves vertically and the wafer 108 rotates in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106 moves in the fashion as described in reference to Figure 23C while, at the same time, the wafer 108 is rotated in direction 112 by using rollers 102a, 102b, and 102c as discussed in reference to the Figures.

Figure 24A shows a proximity head 106-5 that may be utilized for vertical scanning of a wafer in accordance with one embodiment of the present invention. In one embodiment, the proximity head 106-5 is at least as long as the diameter of the wafer 108 so the proximity head 106-5 can produce a meniscus that encompasses at least a diameter of the wafer. In another embodiment, the proximity head 106-5 is long enough so the meniscus produced by the proximity head 106-5 can extend across the diameter of the wafer so as to include the regions of the wafer surface enclosed within the exclusion region. Therefore, by use of the proximity head 106-5, an entire wafer surface may be scanned in one pass. The proximity head 106-5 includes source inlets 302 and 306 and source outlets 304. In one embodiment, there is a plurality of source inlets 306 that is in a shape of a line that is surrounded by a plurality of source outlets 304 that forms a

rectangular shape. Two lines of source inlets 302 are adjacent to the plurality of source outlets 304. In one embodiment, the source inlets 302 and 306 as well as the source outlets 304 may make up the process window where the meniscus 116 may be formed. It should also be appreciated that the proximity head 106-5 as well as the other proximity heads described herein may be varied in size to have different sizes and configurations of process windows. By varying the configuration of the process windows, the size, shape, and the functionality of the meniscus may be changed. In one embodiment, the range of sizes of the proximity head, the sizes of the source inlets 302 and 306 as well as source outlets 304, and the sizes of the ports 342a, 342b, and 342c (as shown in Figures 24B and 24C) are as described above in reference to Figures 11-14. Therefore, the proximity head 106-5 may be any suitable size and configuration depending on the application desired.

For example, if one proximity head is desired to scan an entire 200 mm wafer in one pass, the proximity head 106-5 may have to have a process window that produces a meniscus that is at least 200 mm in length. If the exclusionary region of the 200 mm is not desired to be processed, the meniscus may be less that 200 mm in length. In another example, if one proximity head is desired to scan an entire 300 mm wafer in one pass, the proximity head 106-5 may have to have a process window that produces a meniscus that is at least 300 mm in length. If the exclusionary region of the 300 mm is not desired to be processed, the meniscus may be less that 300 mm in length. In yet another embodiment, if a semicircle of the wafer is desired to be processed by a proximity head in one pass, the process window may be a size that would produce a meniscus length that is at least a radius of the wafer. Therefore, the size of the manifold, process window, and the meniscus may be changed depending on the application desired.

Figure 24B shows a side view of the proximity head 106-5 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 106-5 also includes ports 342a, 342b, and 342c that, in one embodiment, correspond to the source inlet 302, source outlet 304, and source inlet 306 respectively. By inputting or removing fluid through the ports 342a, 342b, and 342c, fluids may be inputted or outputted through the source inlet 302, the source outlet 304, and the source inlet 306. Although the ports 342a, 342b, and 342c correspond with the source inlet 302, the source outlet 304, and the

source inlet 306 in this exemplary embodiment, it should be appreciated that the ports 342a, 342b, and 342c may supply or remove fluid from any suitable source inlet or source outlet depending on the configuration desired. Because of the configuration of the source inlets 302 and 306 with the source outlets 304, the meniscus 116 may be formed between the proximity head 106-5 and the wafer 108. The shape of the meniscus 116 may vary depending on the configuration and dimensions of the proximity head 106-5. As shown in Figure 24B, the portion 342c and the source inlet 306 may be configured to angle the input of IPA to the surface of the wafer. As discussed above in reference to Figure 7C and 7D, by use of an angled source inlet 306, the meniscus may be managed efficiently so the shape of the meniscus may be controlled and maintained in an optimal manner. In one embodiment, source inlet 306 may be angled between about 0 degrees and about 90 degrees in the direction of the source outlet 304 where angle 90 would be pointing toward the wafer and the angle 0 would be pointing inward to the source outlet 304. In a preferable embodiment, the source inlet 306 is angled about 15 degrees. It should be understood that the source inlet 302 and source outlet 304 may be angled in any suitable angle that may optimize the generation, control, and management of a stable fluid meniscus.

Figure 24C shows an isometric view of the proximity head 106-5 in accordance with one embodiment of the present invention. The view of the proximity head 106-5 shown in Figure 24C shows a back side opposite the process window which includes connecting holes 580 and aligning holes 582. The connecting holes 580 may be used to attach the proximity head 106-5 to a proximity head carrier. The aligning holes may be utilized to align the manifold depending on the application desired. The proximity head 106-5 also includes ports 342a, 342b, and 342, on a side of the proximity head 106-5 opposite the leading edge of the proximity head 106-5. It should be appreciated that the configuration and location of the ports 342a, 342b, 342c, and connecting holes 580, and the aligning holes 582 may be application dependent and therefore may be any suitable configuration and location as long as the meniscus may be managed in accordance with the descriptions herein.

Figure 25A shows a multi-process window proximity head 106-6 in accordance with one embodiment of the present invention. The proximity head 106-6 includes two process windows 538-1 and 538-2. In one embodiment, the process window 538-2 may use cleaning fluids instead of DIW to clean wafers. The process window 538-2 may use any suitable configuration of source inlets and outlets that may apply any suitable type of cleaning fluid to the wafer. In one embodiment, the process window 538-2 may include only source inlets that may apply the cleaning fluid. In another embodiment, the process window 538-2 may include other configurations and functions of source inlets and outlets described herein.

The process window 538-1 may then dry the wafer. The process window 538-1 may use any suitable configurations of source inlets and source outlets consistent with the configurations and functions described herein for drying a wafer surface. Therefore, by use of multiple process windows multiple functions such as cleaning and drying may be accomplished by one proximity head. In yet another embodiment, instead of multiple process windows being located on one proximity head, multiple proximity heads may be utilized to process the wafer where, for example, one proximity head may clean the wafer and another proximity head may dry the wafer according to the apparatuses and methodology described herein.

Figure 25B shows a multi-process window proximity head 106-7 with three process windows in accordance with one embodiment of the present invention. It should be appreciated that the proximity head 106-7 may include any suitable number of processing windows depending on the number and types of processing desired to be accomplished by the proximity head 106-7. In one embodiment, the proximity head 106-7 includes a process window 538-1, 538-2, and 538-3. In one embodiment, the process window 538-1, 538-2, and 538-3 are cleaning, rinsing/drying, and drying process windows respectively. In one embodiment, the process window 538-1 may form a meniscus made up of DIW to rinse a wafer surface. The process window 538-2 may generate a cleaning fluid meniscus to clean a wafer surface. The process windows 538-1 and 538-2 includes at least one source inlet 306 to apply fluid to the wafer surface. In one embodiment, the process windows 538-1 and 538-2 may optionally include source inlet 302 and source

outlet 304 to generate a stable and controllable fluid meniscus. The process window 538-3 may generate the fluid meniscus 116 to dry the wafer. It should be appreciated that the process window 538-3 both rinses and dries the wafer surface because the fluid meniscus is made up of DIW. Therefore, different types of process windows may be included in the proximity head 106-7. As discussed in reference to Figure 25A above, instead of having multiple process windows in one proximity head, multiple proximity heads may be used where one or more of the proximity heads may be used for different purposes such as cleaning, rinsing, drying, etc.

While this invention has been described in terms of several preferred embodiments, it will be appreciated that those skilled in the art upon reading the preceding specifications and studying the drawings will realize various alterations, additions, permutations and equivalents thereof. It is therefore intended that the present invention includes all such alterations, additions, permutations, and equivalents as fall within the true spirit and scope of the invention.

What is claimed is:

CLAIMS

1. A substrate preparation system, comprising:

a head having a head surface, the head surface configured to be proximate to a surface of the substrate when in operation;

at least one of a first conduit for delivering a first fluid to the surface of the substrate through the head;

at least one of a second conduit for delivering a second fluid to the surface of the substrate through the head, the second fluid being different than the first fluid; and

at least one of a third conduit for removing each of the first fluid and the second fluid from the surface of the substrate, the at least one of the third conduit being located to substantially surround the at least one of the first conduit, wherein the at least one of the first conduit, the at least one of the second conduit, and the at least one of the third conduit being configured to act substantially simultaneously when in operation;

wherein the at least one of the second conduit is located to substantially surround at least a portion of the at least one of the third conduit.

2. A substrate preparation system as recited in claim 1, wherein the substrate moves along a specified motion profile so that the head traverses the surface of the substrate.

3. A method for processing a substrate, comprising:

applying a first fluid onto a first region of a surface of the substrate;

applying a second fluid onto a second region of the surface of the substrate; and

removing the first fluid and the second fluid from the surface of the substrate, the removing occurring from a third region that substantially surrounds the first region;

wherein the second region substantially surrounds at least a portion of the third region, and the applying and the removing forms a controlled fluid meniscus.

4. A method for processing substrate as recited in claim 3, further comprising: scanning the controlled meniscus over the surface of the substrate.

5. A method for processing substrate as recited in claim 3, wherein the first fluid is one of DIW and a cleaning fluid.

6. A method for processing substrate as recited in claim 3, wherein the second fluid is one of isopropyl alcohol (IPA) vapor, nitrogen, organic compounds, hexanol, ethyl glycol, and compounds miscible with water.

7. A method for processing substrate as recited in claim 3, wherein the removing the first fluid and the second fluid includes applying a vacuum in close proximity to the surface of the substrate.

8. A method for processing substrate as recited in claim 3, wherein the meniscus extends up to a diameter of the substrate.

9. A substrate preparation system, comprising:

a manifold having a surface, the surface configured to be proximate to a surface of the substrate when in operation;

at least one of a first source inlet for delivering a first fluid to the surface of the substrate through the manifold;

at least one of a second source inlet for delivering a second fluid to the surface of the substrate through the manifold, the second fluid being different than the first fluid; and

at least one of a source outlet for removing each of the first fluid and the second fluid from the surface of the substrate, the at least one of the source outlet being located to substantially surround the at least one of the first source inlet, and the at least one of the first source inlet, the at least one of the second source inlet, and the at least one of the source outlet being configured to act substantially simultaneously when in operation;

wherein the at least one of the second source inlet surrounds at least a trailing edge side of the at least one of the source outlet.

10. A head for use in preparing a wafer surface, comprising:

a first surface of the head, the first surface capable of being placed in close proximity to the wafer surface;

a first conduit region on the head, the first conduit region defined for delivery of a first fluid to wafer of the surface, the first conduit region defined in a center portion of the head;

a second conduit region on the head, the second conduit region being configured to surround the first conduit region; and

a third conduit region on the head, the third conduit region defined for delivery of a second fluid to the wafer surface, the third conduit region defining a semi-enclosure of the first conduit region and the second conduit region;

wherein second conduit region enabling a removal of the first fluid and the second fluid, and wherein the delivery of the first fluid and the second fluid combined with the removal by the third conduit region of the head defines a controllable meniscus that is defined between the head and the wafer surface when in operation and the head is proximate to the wafer surface.

11. A head for use in preparing a wafer surface as recited in claim 10, wherein an opening exists in the semi-enclosure.

12. A head for use in preparing a wafer surface as recited in claim 10, wherein the wafer surface is capable of being scanned by the head where the opening of the semi-enclosure leads in the direction of scanning.

13. A cluster architecture system for processing a wafer, comprising:

an integrated drying system, the integrated drying system including at least one proximity head for drying a substrate; and

processing modules coupled to the integrated drying system, the processing modules selected from one or more of a chemical mechanical planarization module, a megasonic processing module, a cleaning module, and an etching module.

14. A cluster architecture system for processing a wafer as recited in claim 13, wherein the cleaning module is one of a brush box and a spin rinse and dry (SRD) module.

15. A cluster architecture system for processing a wafer as recited in claim 13, further comprising:

a front end loader which loads the substrate into one of the cleaning module, the megasonic processing module, the CMP module, the etching module, and the integrated drying system.

16. A cluster architecture system for processing a wafer as recited in claim 15, wherein a robot loads the wafer from the front end loader to one of the cleaning module, the megasonic processing module, the CMP module, the etching module, and the integrated drying system.

17. A cluster architecture system for processing a wafer as recited in claim 16, wherein the robot transports the substrate between the etching module, the cleaning module, the CMP module, the megasonic module, and the integrated drying system.

18. A cluster architecture system for processing a wafer as recited in claim 13, wherein the integrated drying system includes,

a proximity head carrier assembly configured to scan the substrate, the proximity head carrier assembly including,

a first proximity head being disposed over a substrate;

a second proximity head being disposed under the substrate;

an upper arm connected with the first proximity head, the upper arm being configured so the first proximity head is movable into close proximity over the substrate to initiate substrate preparation; and

a lower arm connected with the second proximity head, the lower arm being configured so the second proximity head is movable into close proximity under the substrate to initiate substrate preparation.

19. A cluster architecture system for processing a wafer as recited in claim 18, wherein the proximity head includes,

a first surface of the head, the first surface capable of being placed in close proximity to the substrate surface;

a first conduit region on the head, the first conduit region defined for delivery of a first fluid to the substrate surface, the first conduit region defined in a center portion of the head;

a second conduit region on the head, the second conduit region being configured to surround the first conduit region; and

a third conduit region on the head, the third conduit region defined for delivery of a second fluid to the substrate surface, the third conduit region defining a semi-enclosure of the first conduit region and the second conduit region;

wherein second conduit region enabling a removal of the first fluid and the second fluid, and wherein the delivery of the first fluid and the second fluid combined with the removal by the third conduit region of the head defines a controllable meniscus that is defined between the head and the substrate surface when in operation and the head is proximate to the substrate surface.

20. A method for processing a substrate, the substrate being substantially vertically oriented, comprising:

generating a fluid meniscus on the surface of the vertically oriented substrate; and

moving the fluid meniscus over the surface of the vertically oriented substrate to process the surface of the substrate.

21. A method for processing a substrate as recited in claim 20, wherein generating the fluid meniscus includes,

applying a first fluid onto a first region of the surface of the substrate;

applying a second fluid onto a second region of the surface of the substrate; and

removing the first fluid and the second fluid from the surface of the substrate, the removing occurring from a third region that substantially surrounds the first region;

wherein the second region substantially surrounds at least a portion of the third region, and the applying and the removing forms the fluid meniscus.

22. A method for processing substrate as recited in claim 21, wherein the first fluid is one of DIW and a cleaning fluid.

23. A method for processing substrate as recited in claim 21, wherein the second fluid is one of isopropyl alcohol (IPA) vapor, organic compounds, hexanol, ethyl glycol, and compounds miscible with water.

24. A method for processing substrate as recited in claim 21, wherein the removing the first fluid and the second fluid includes applying a vacuum in close proximity to the surface of the substrate.

25. A method for processing substrate as recited in claim 20, wherein the meniscus extends to at least a diameter of the substrate and moves from a top region of the wafer to a bottom region of the wafer.

26. A method for processing substrate as recited in claim 20, wherein the processing the surface of the substrate includes at least one of a drying, rinsing, and cleaning operation.

27. A method for processing substrate as recited in claim 20, wherein generating the meniscus includes,

supplying a first fluid at a first region on the surface of the substrate;

surrounding the first region with a vacuum region;

semi-enclosing the vacuum region with an applied surface tension reducing fluid region, the semi-enclosing defining an opening that leads to the vacuum region.

28. A method for processing a substrate as recited in claim 20, further comprising:

generating an additional fluid meniscus on an additional surface of the vertically oriented substrate; and

moving the additional fluid meniscus over the additional surface of the vertically oriented substrate to process the additional surface of the substrate.

29. A substrate preparation apparatus to be used in substrate processing operations, comprising:

an arm capable of vertical movement between a first edge of the substrate to a second edge of the substrate; and

a head coupled to the arm, the head being capable of forming a fluid meniscus on a surface of the substrate and capable of being moved over the surface of the substrate.

30. A substrate preparation apparatus as recited in claim 29, wherein the head includes,

at least one of a first source inlet for delivering a first fluid to the surface of the substrate through the head;

at least one of a second source inlet for delivering a second fluid to the surface of the substrate through the head, the second fluid being different than the first fluid; and

at least one of a source outlet for removing each of the first fluid and the second fluid from the surface of the substrate, the at least one of the source outlet being located to substantially surround the at least one of the first source inlet, and the at least one of the first source inlet, the at least one of the second source inlet, and the at least one of the source outlet being configured to act substantially simultaneously when in operation;

wherein the at least one of the second source inlet surrounds at least a trailing edge side of the at least one of the source outlet.

31. A substrate preparation apparatus as recited in claim 29, wherein the arm is configured to move the head down a diameter of the substrate.

32. A substrate preparation apparatus as recited in claim 29, wherein the head extends at least a diameter of the substrate.

33. A manifold for use in preparing a wafer surface, comprising:

a first process window in a first portion of the manifold being configured generate a first fluid meniscus on the wafer surface; and

a second process window in a second portion of the manifold being configured to generate a second fluid meniscus on the wafer surface.

34. A manifold for use in preparing a wafer surface as recited in claim 33, wherein the first fluid meniscus cleans the wafer surface and the second fluid meniscus cleans and dries the wafer surface.

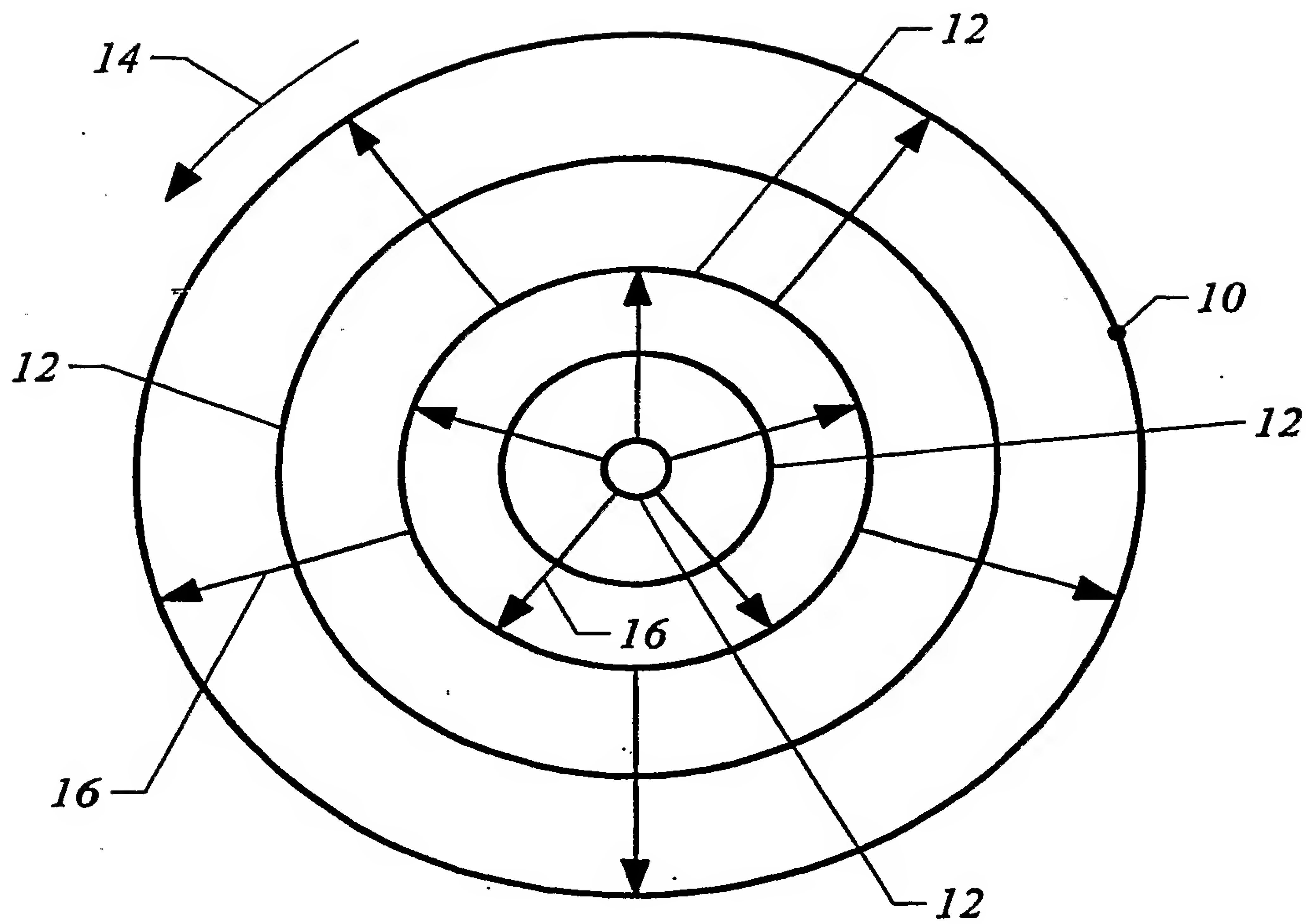


FIG. 1
(Prior Art)

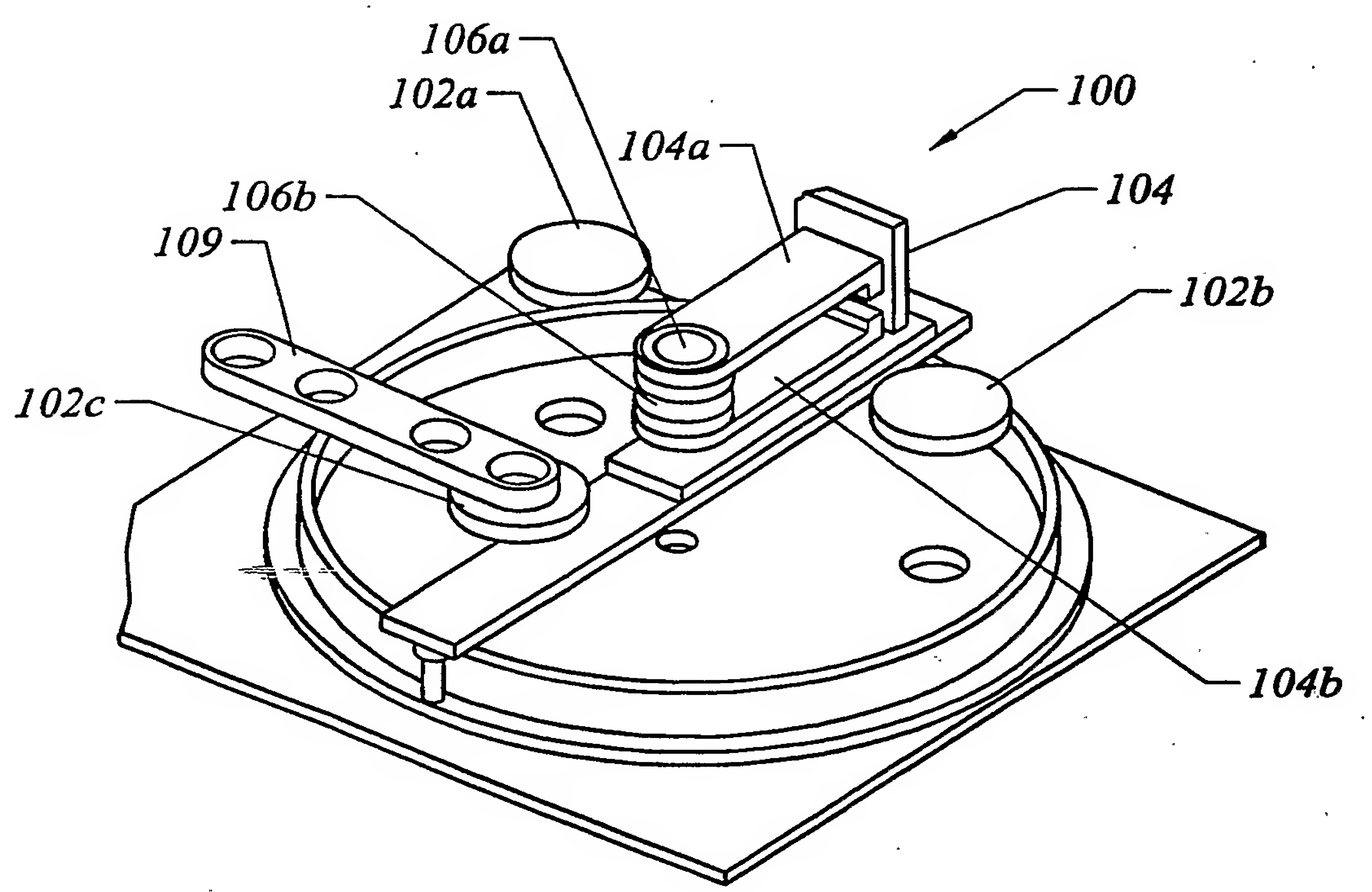

106a
102a
100
104a
104
106b
109
102b
102c
104b

FIG. 2A

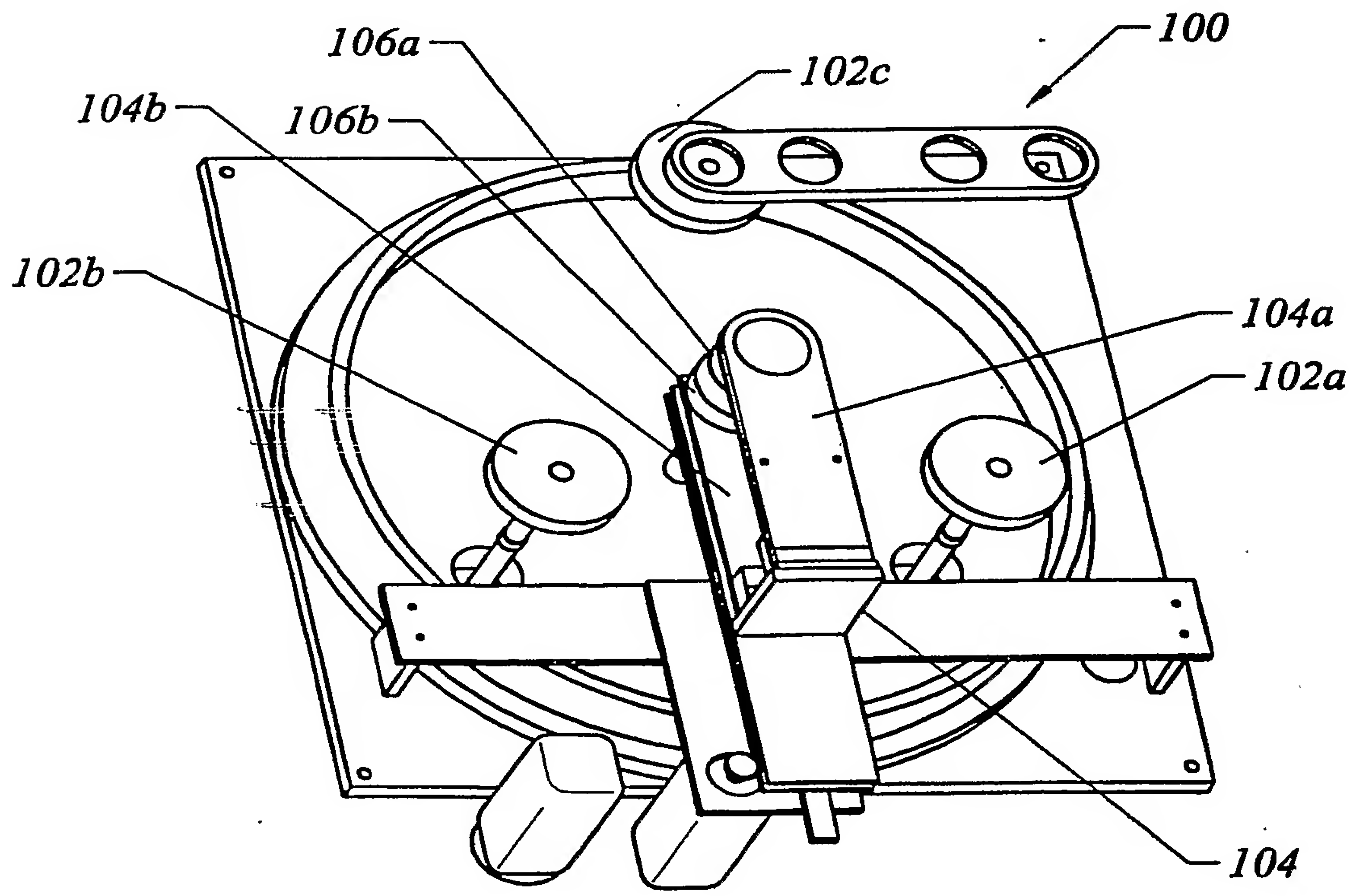

100
106a
102c
104b
106b
102b
104a
102a
104

FIG. 2B

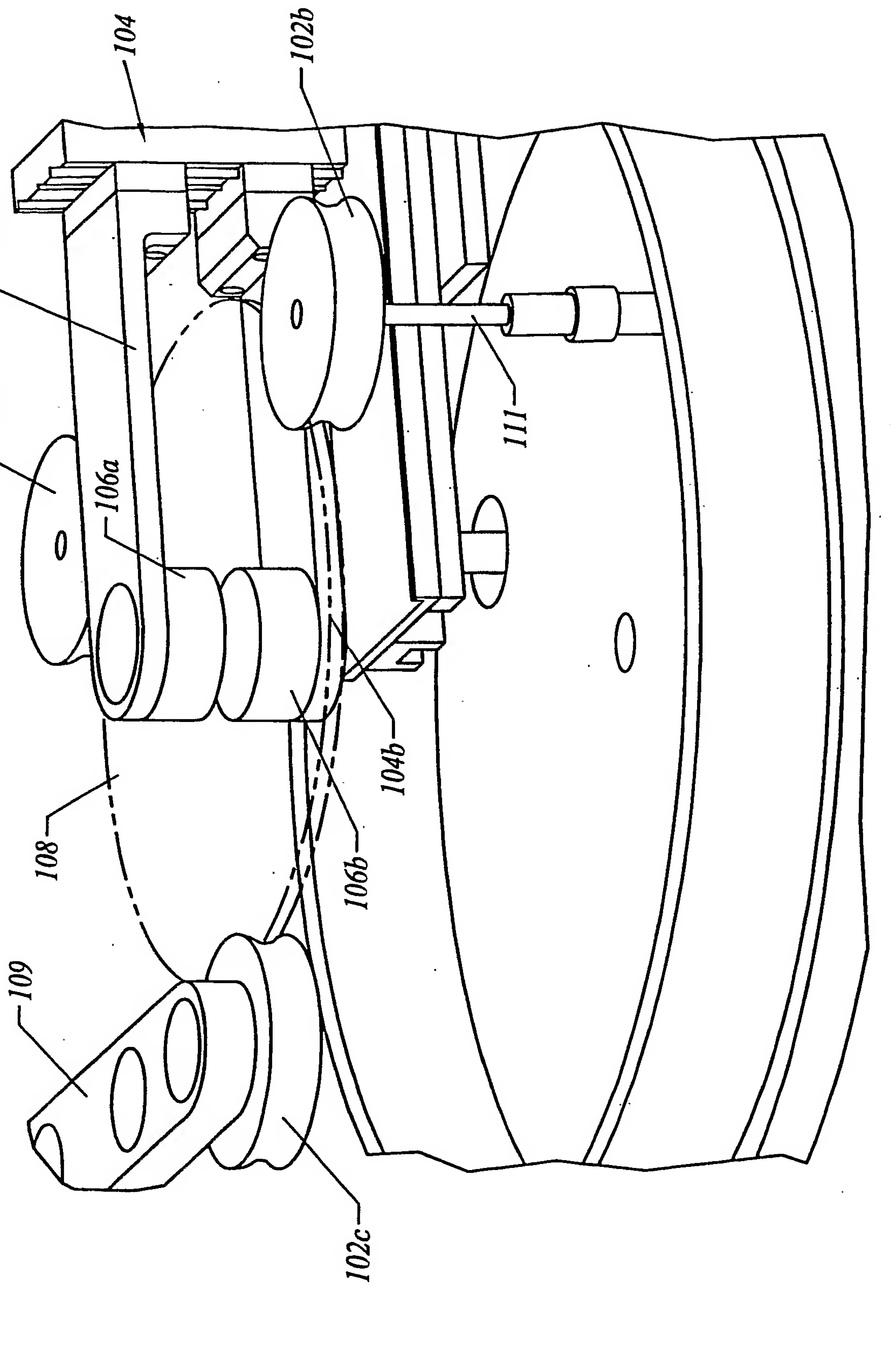


FIG. 2C

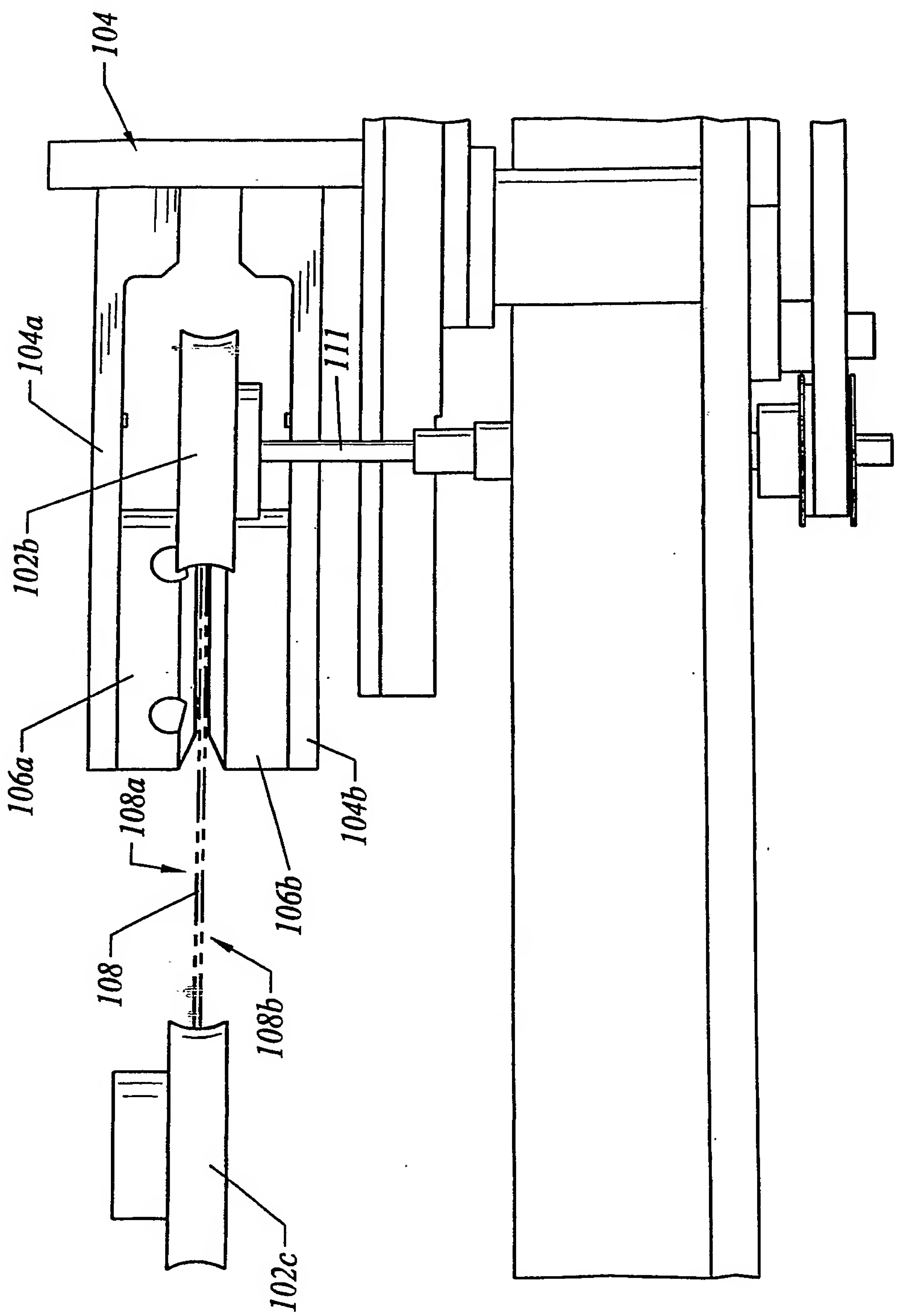


FIG. 2D

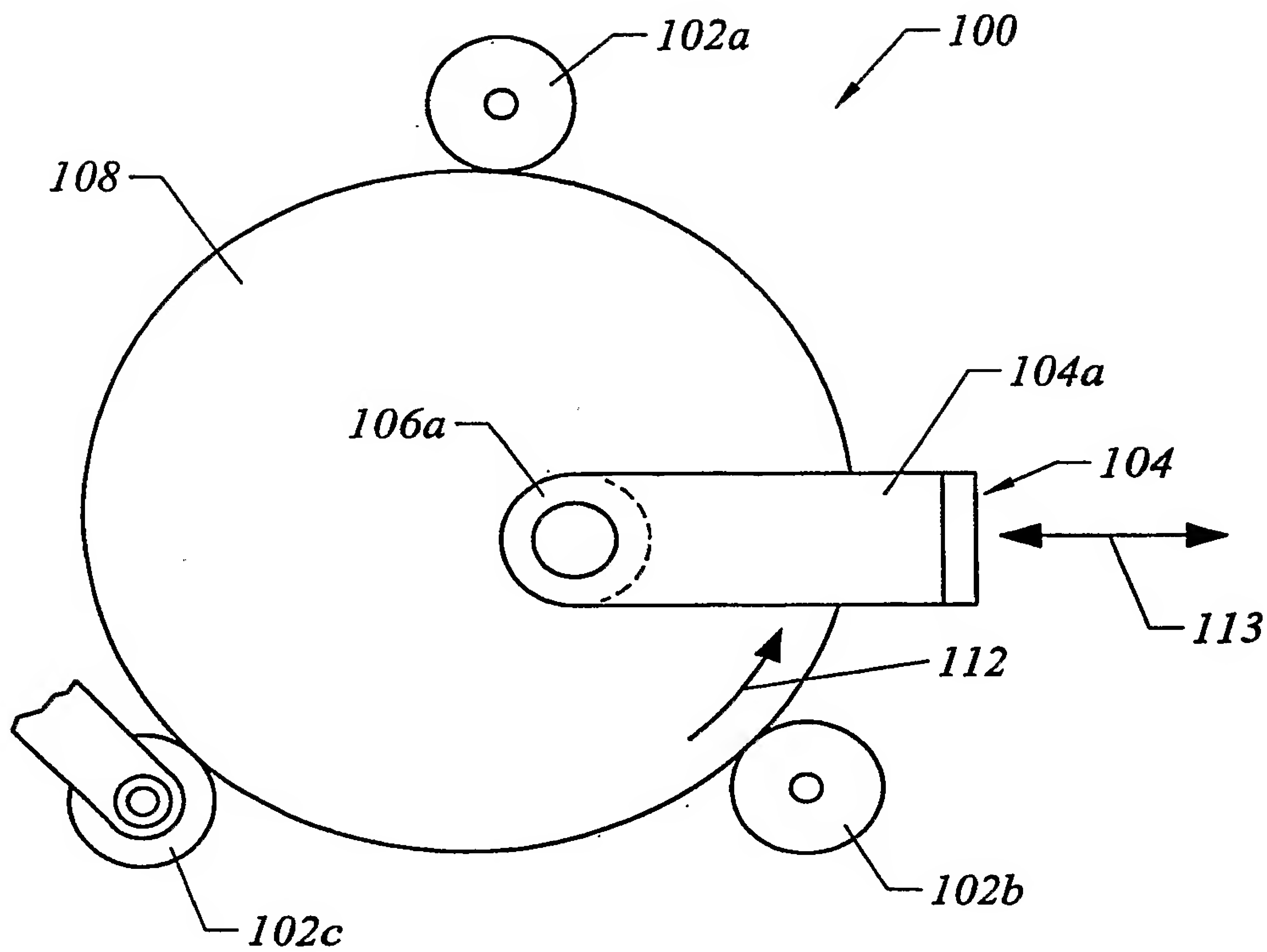

100
102a
108
104a
106a
104
113
112
102b
102c

FIG. 3A

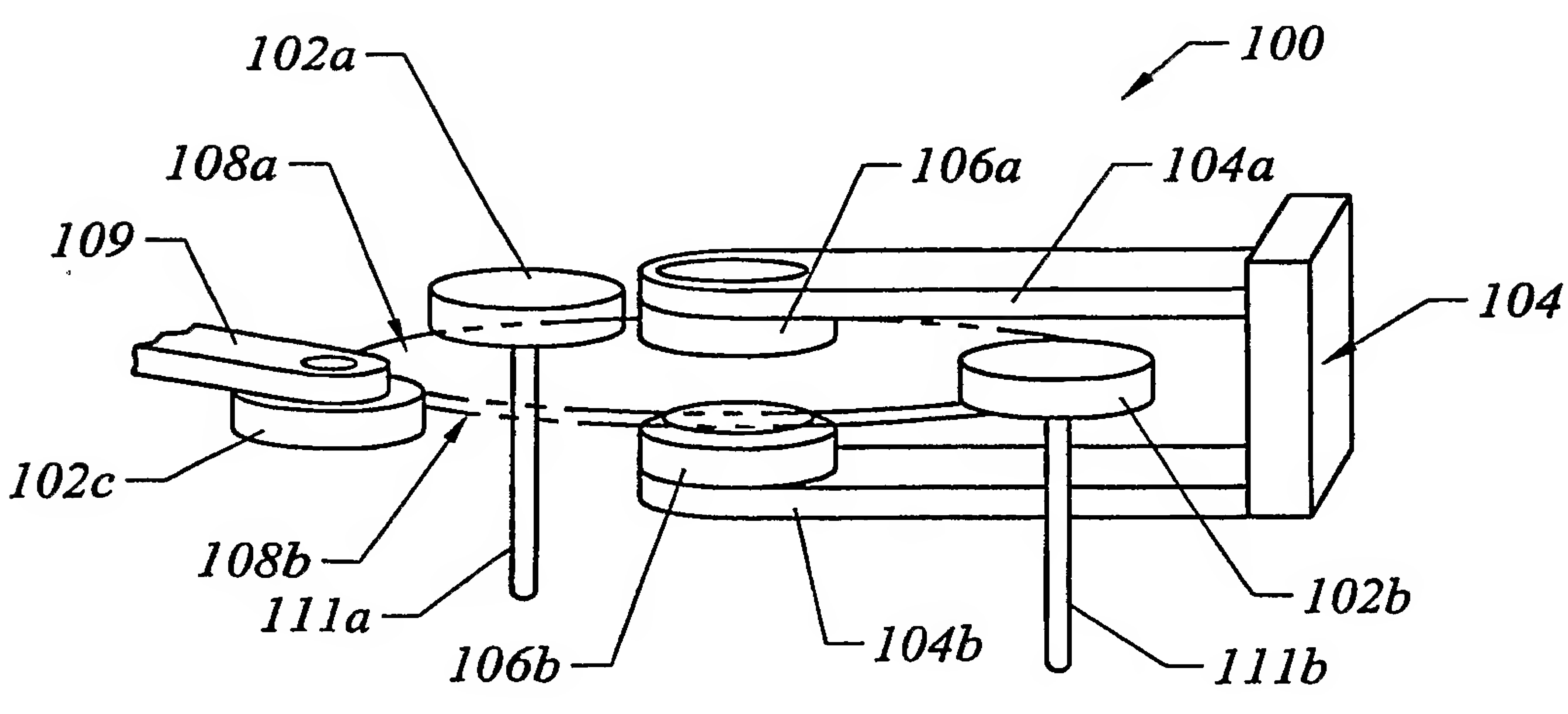

100
102a
108a
106a
104a
109
104
102c
108b
102b
111a
106b
104b
111b

FIG. 3B

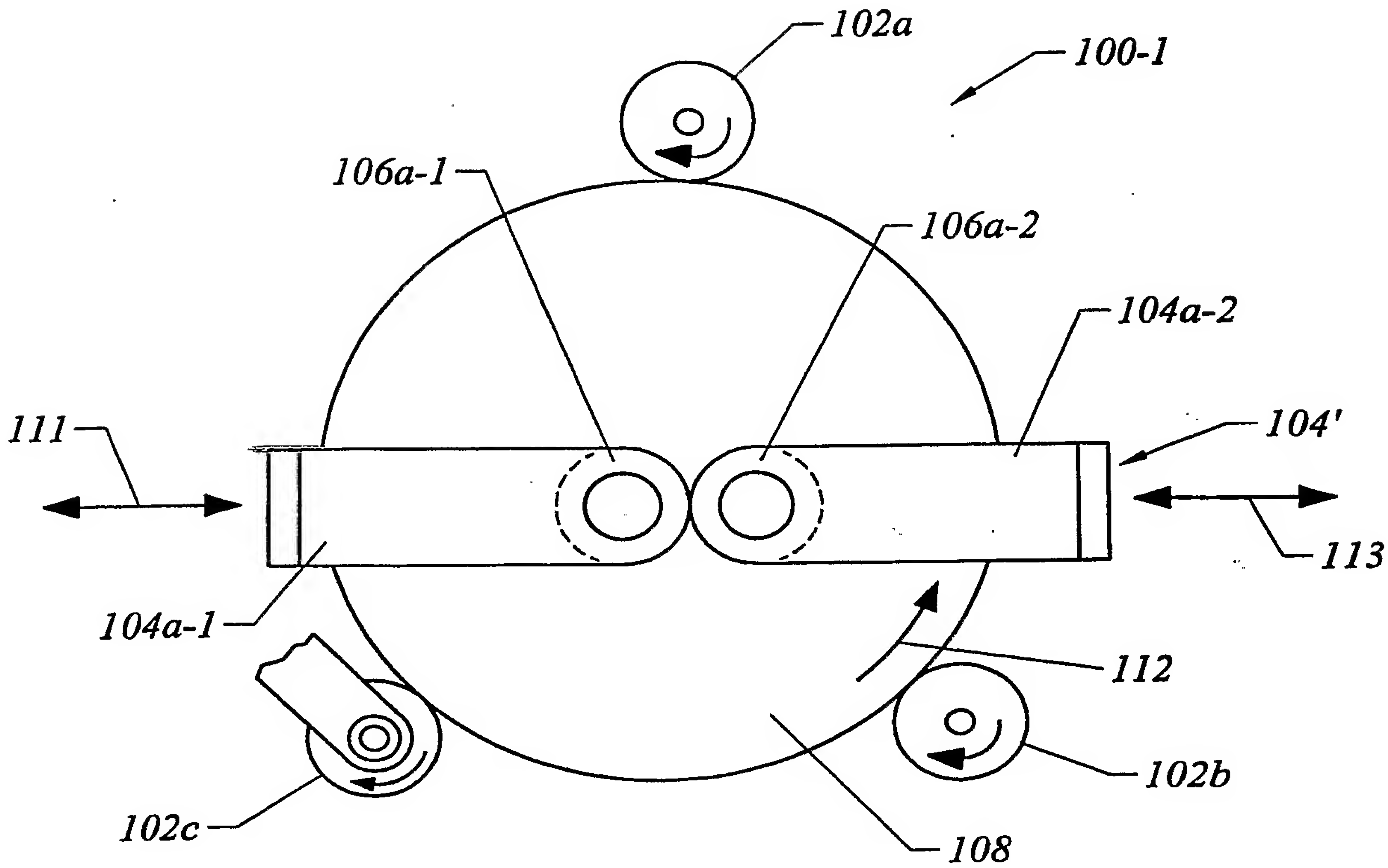

102a
100-1
106a-1
106a-2
104a-2
111
104'
113
104a-1
112
102b
102c
108

FIG. 4A

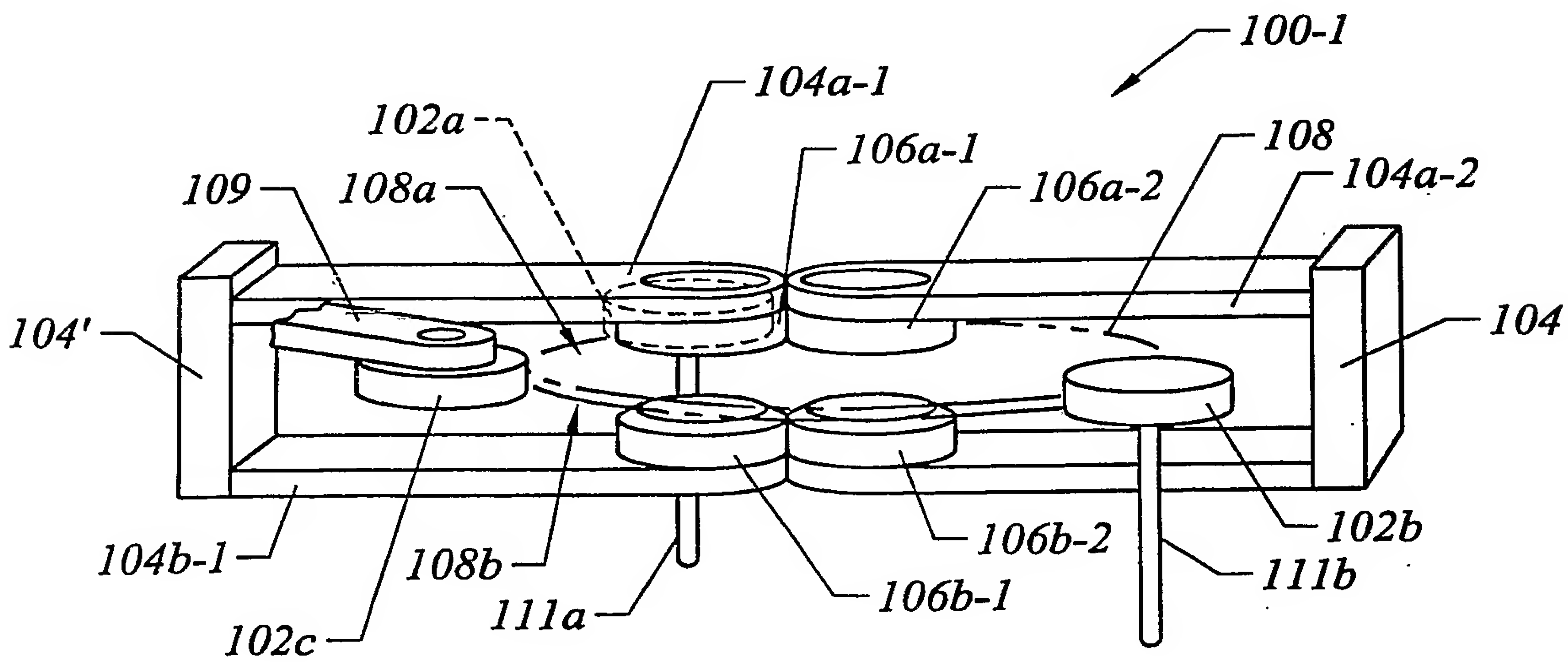

100-1
104a-1
102a
106a-1
108
104a-2
109
108a
106a-2
104'
104'
104b-1
108b
106b-2
102b
111b
111a
106b-1
102c

FIG. 4B

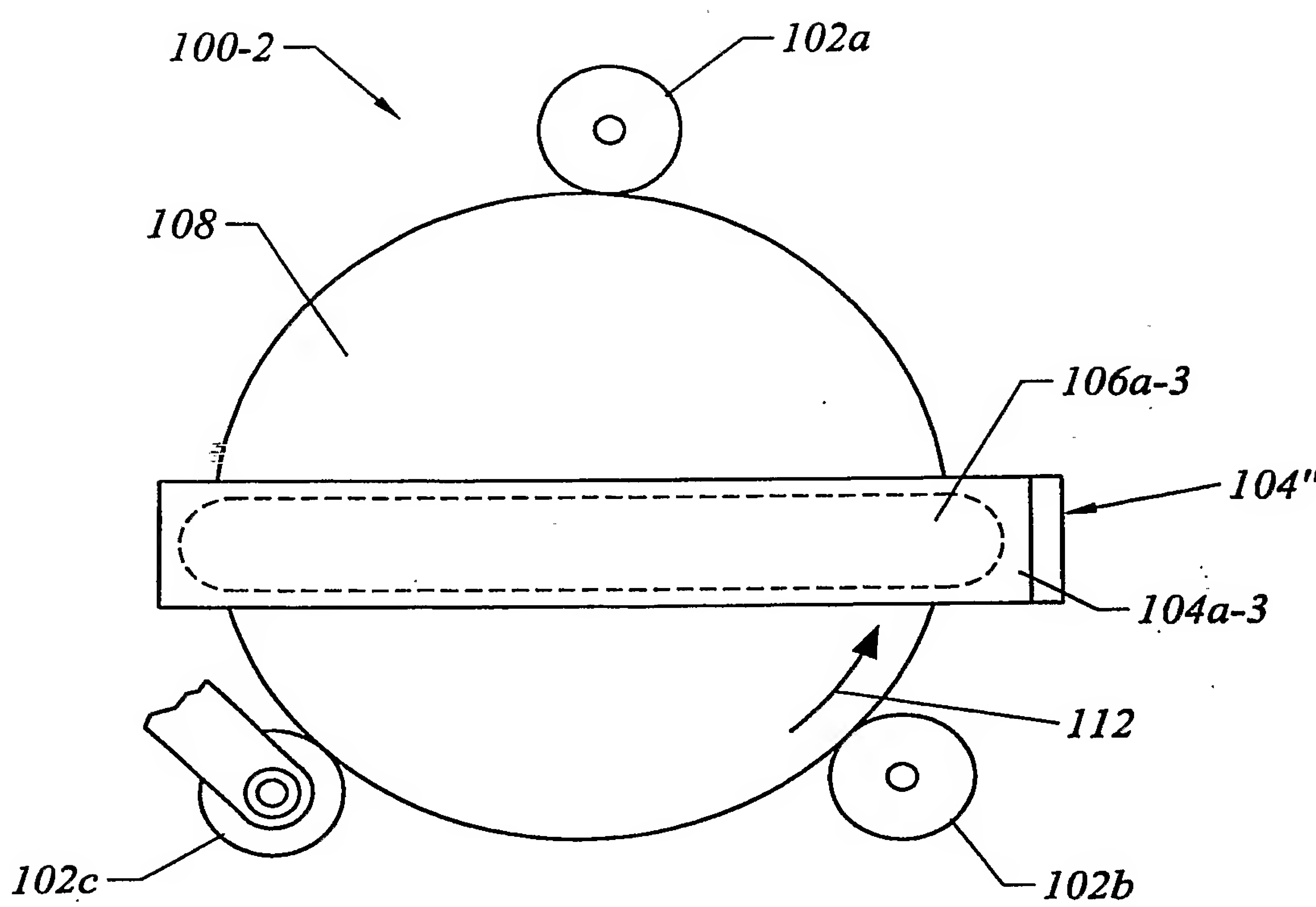

100-2
102a
108
106a-3
104"
104a-3
112
102c
102b

FIG. 5A

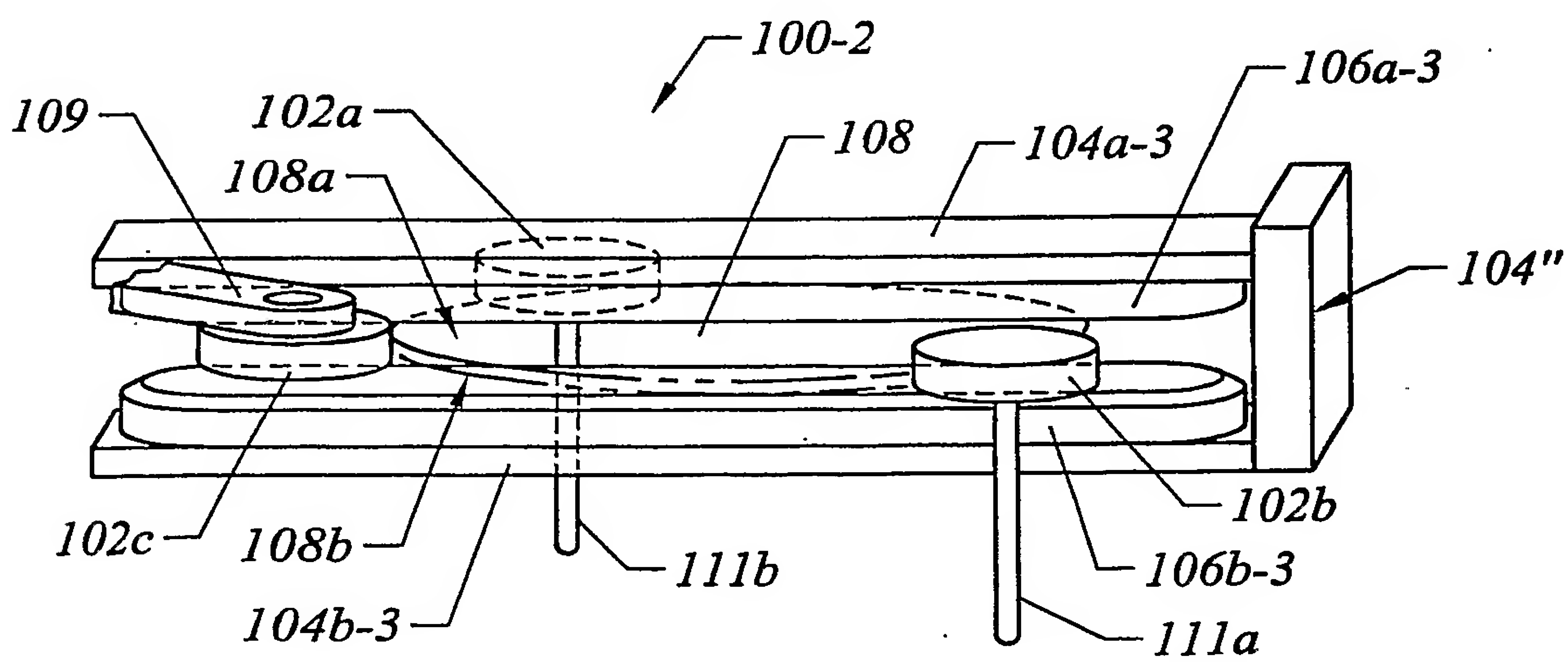

100-2
109
102a
106a-3
108a
108
104a-3
104"
102c
108b
111b
102b
106b-3
104b-3
111a

FIG. 5B

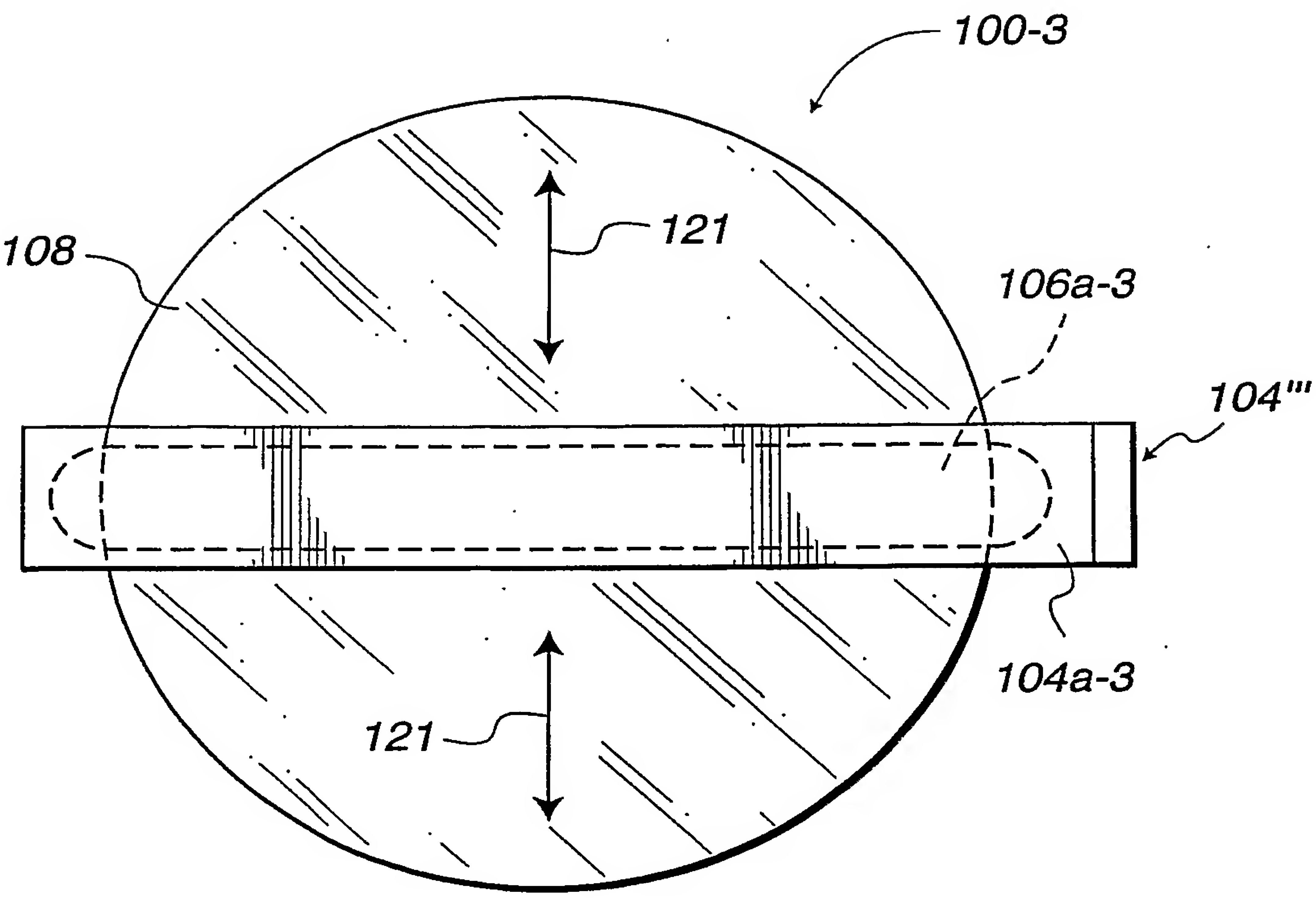

100-3
121
108
106a-3
104'''
104a-3
121

FIG. 5C

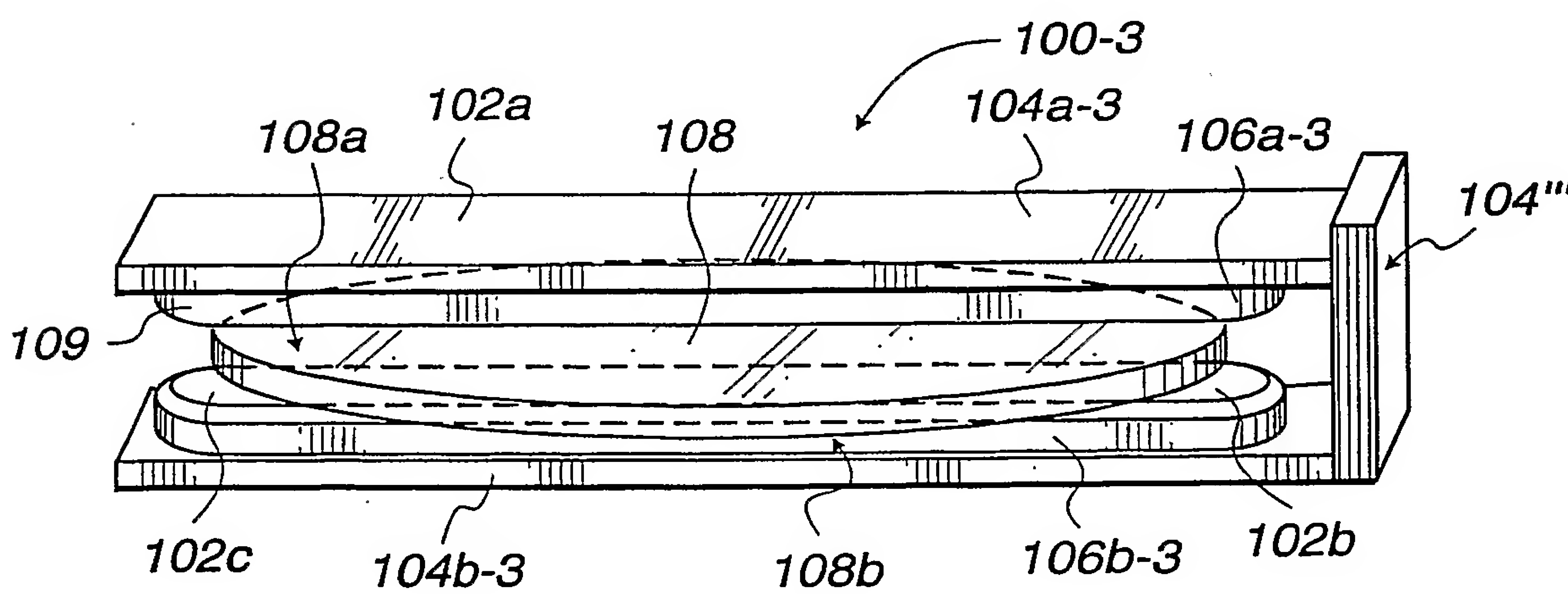

100-3
102a
108a
108
104a-3
106a-3
104'''
109
102c
104b-3
108b
106b-3
102b

FIG. 5D

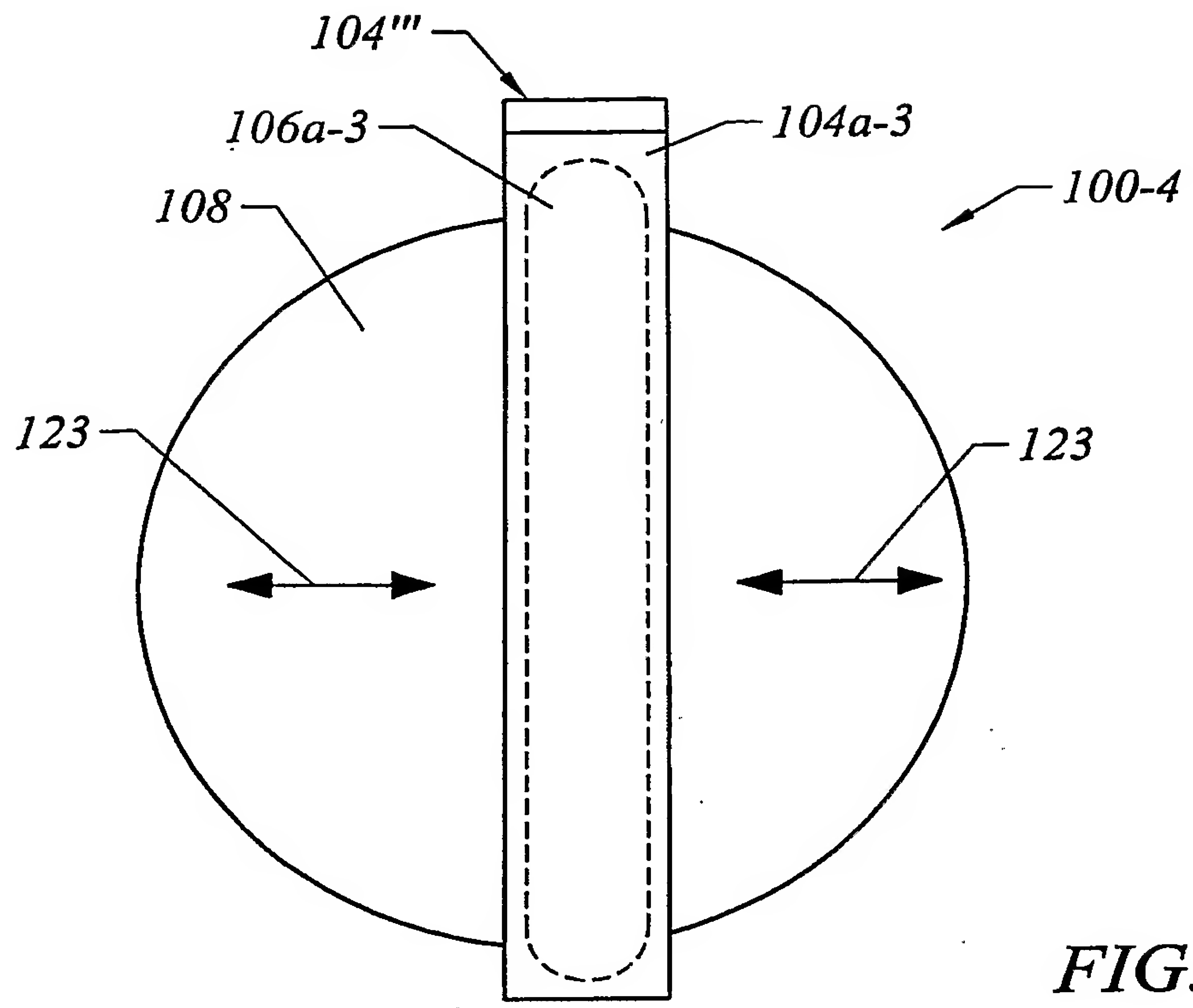

104'''
106a-3
104a-3
100-4
108
123
123

FIG. 5E

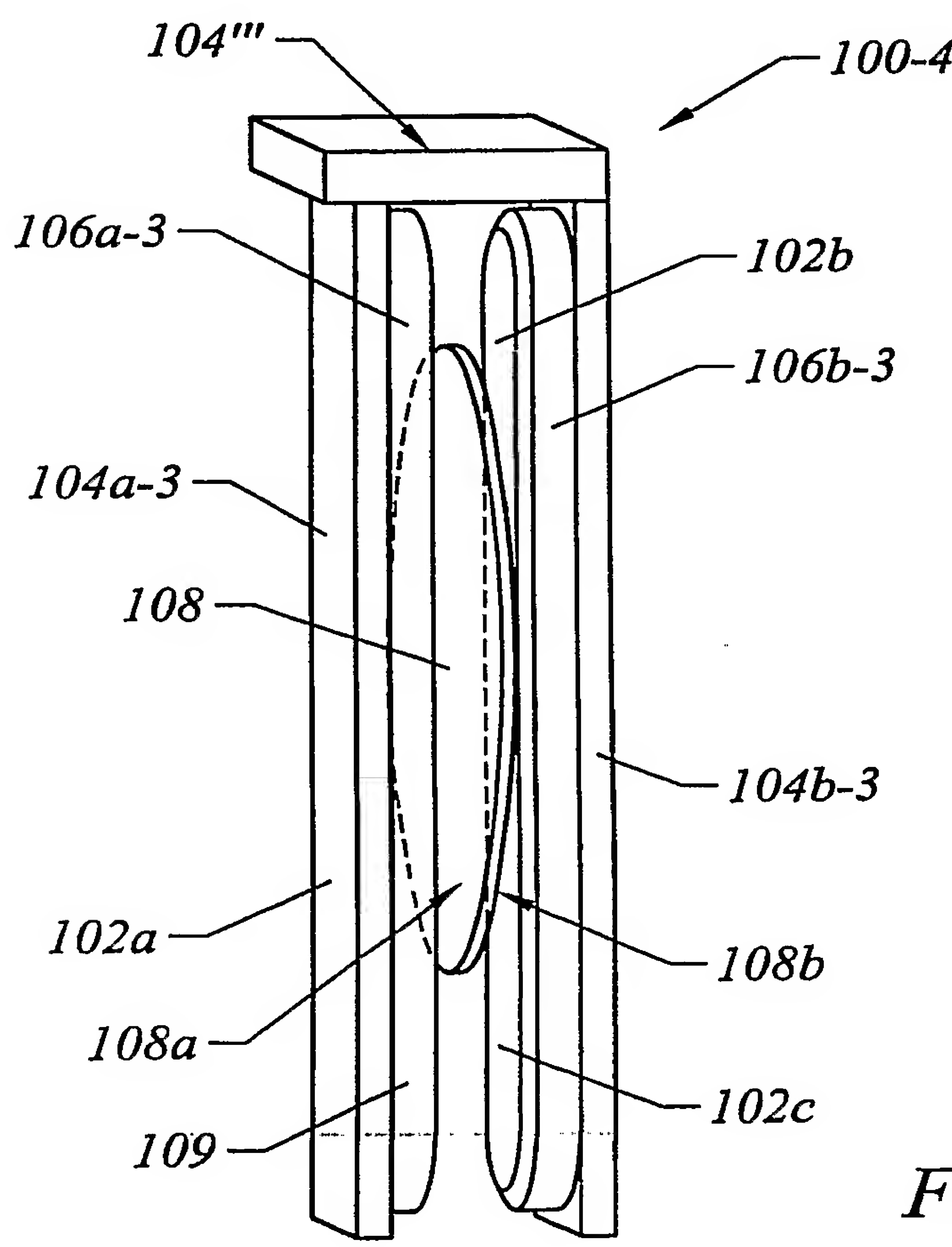

104'''
100-4
106a-3
102b
106b-3
104a-3
108
104b-3
102a
108b
108a
102c
109

FIG. 5F

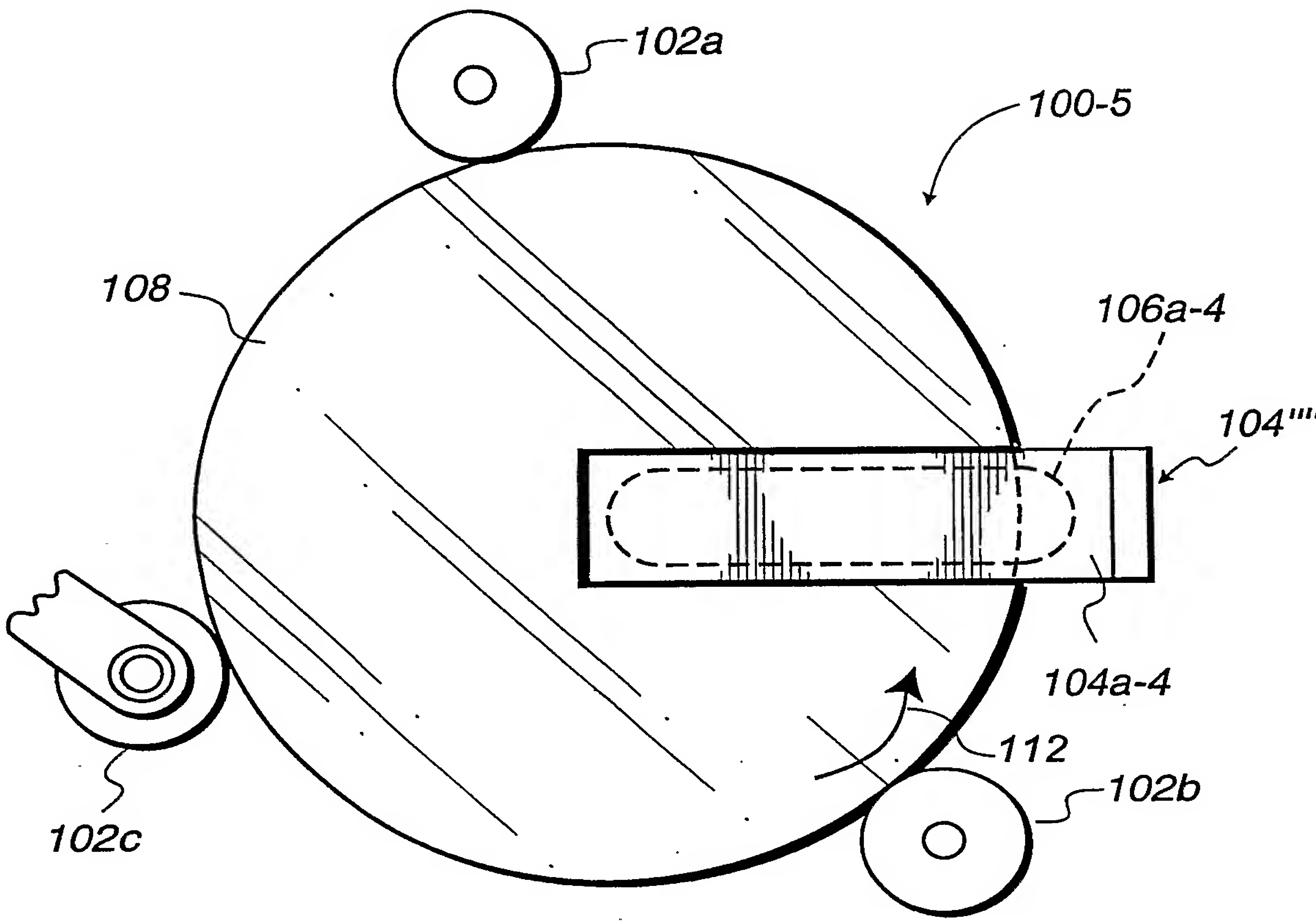

102a
100-5
108
106a-4
104'''''
104a-4
112
102b
102c

FIG. 5G

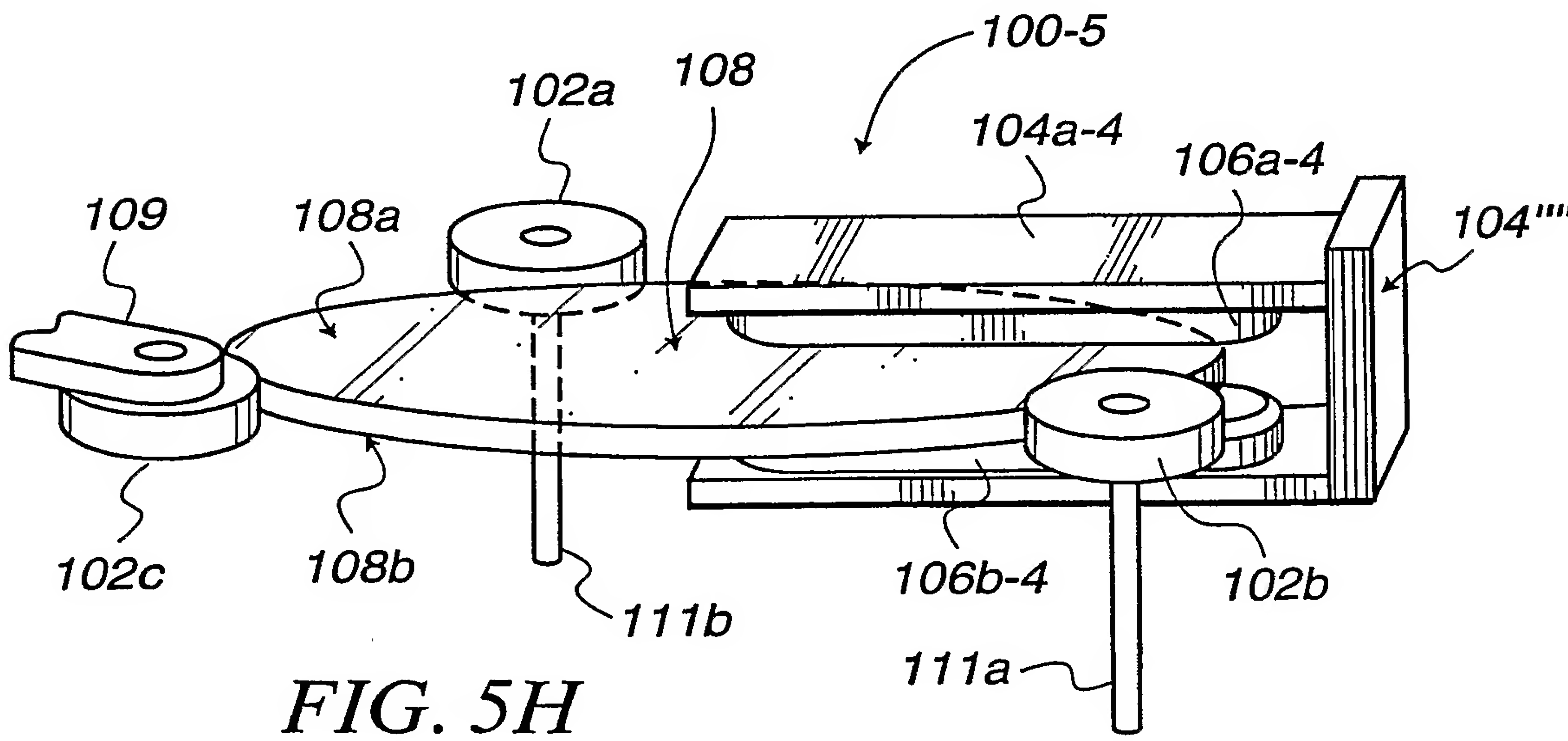

100-5
102a
108
104a-4
106a-4
109
108a
104'''''
102c
108b
111b
106b-4
102b
111a

FIG. 5H

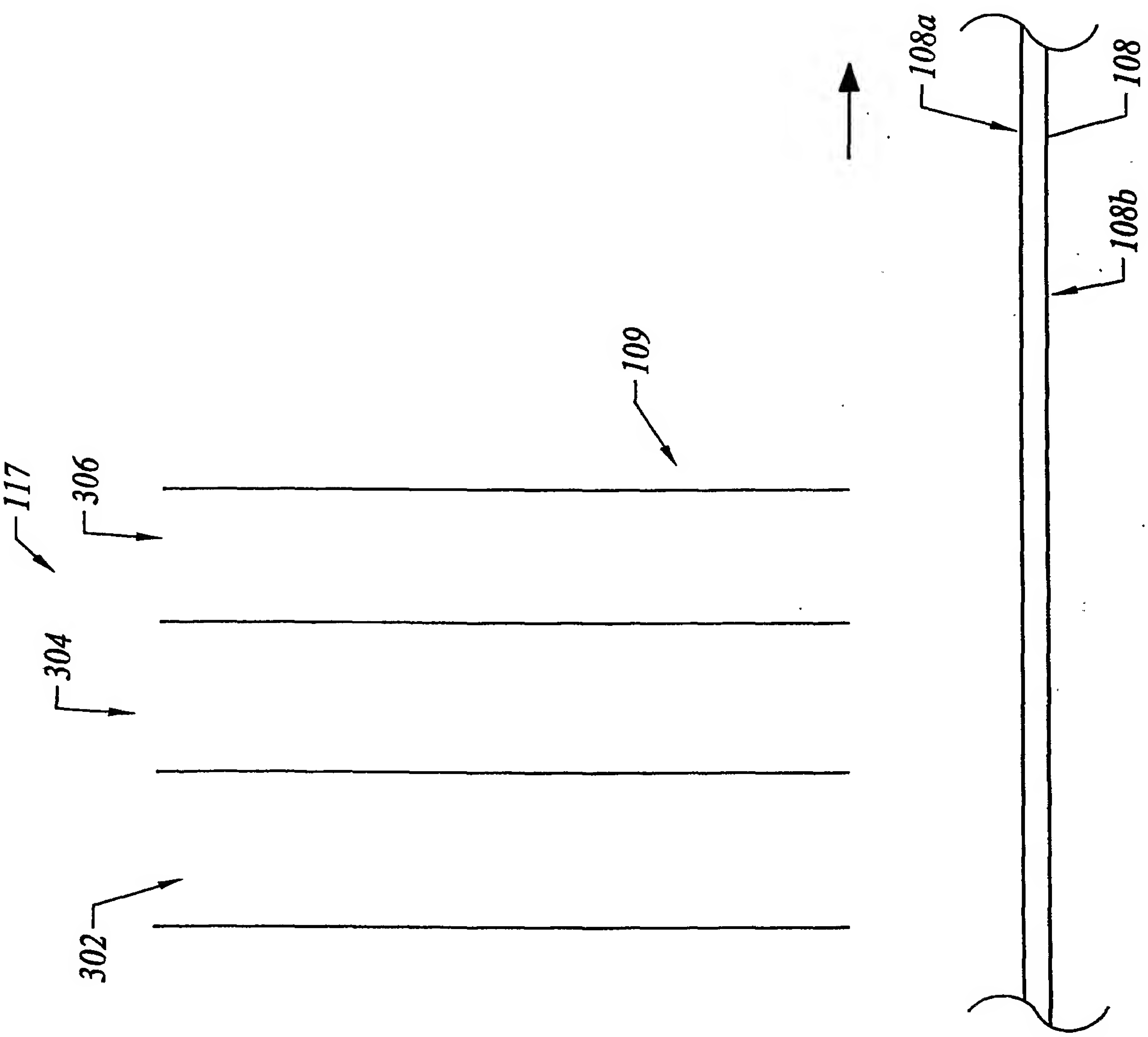


FIG. 6A

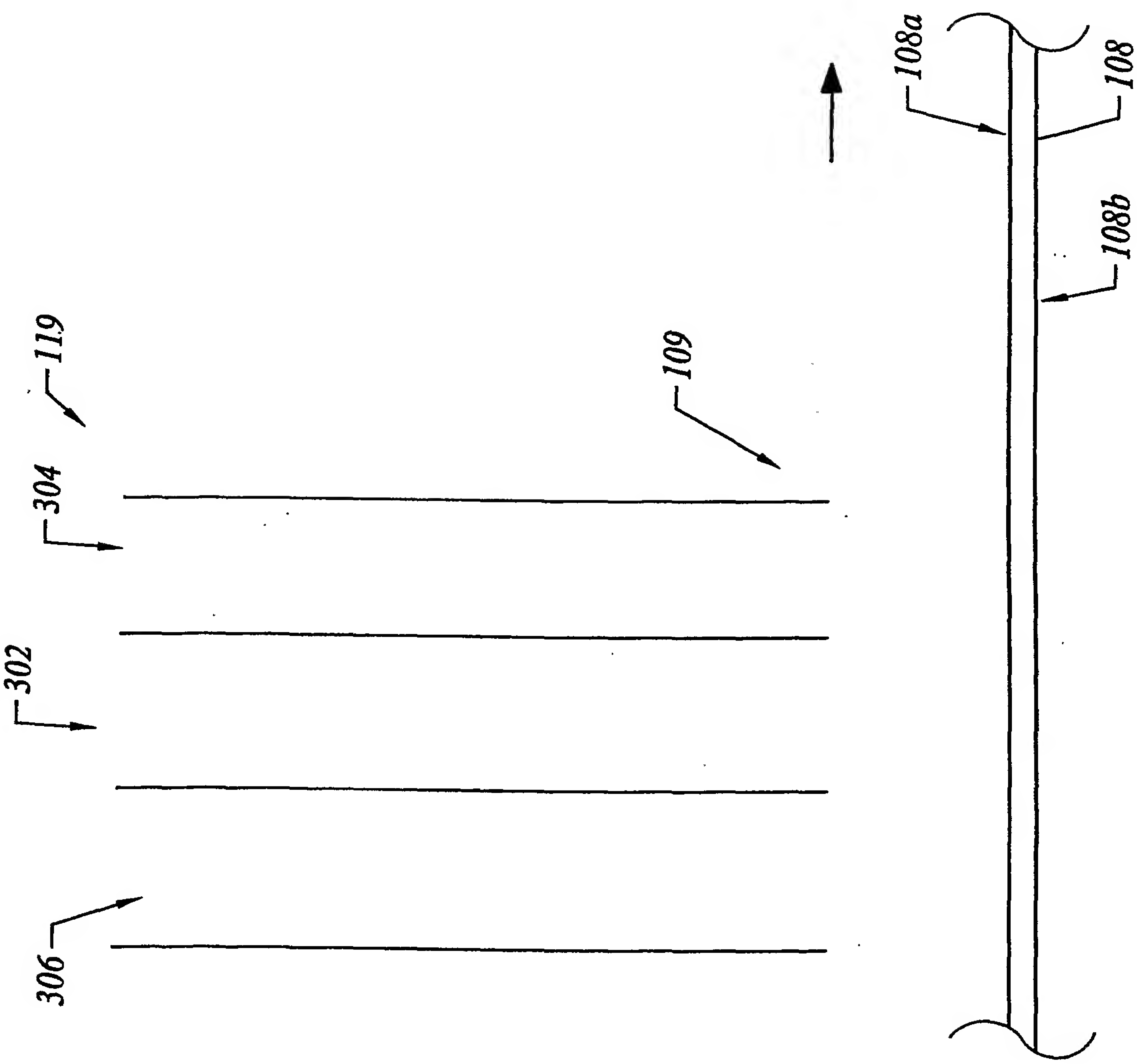


FIG. 6B

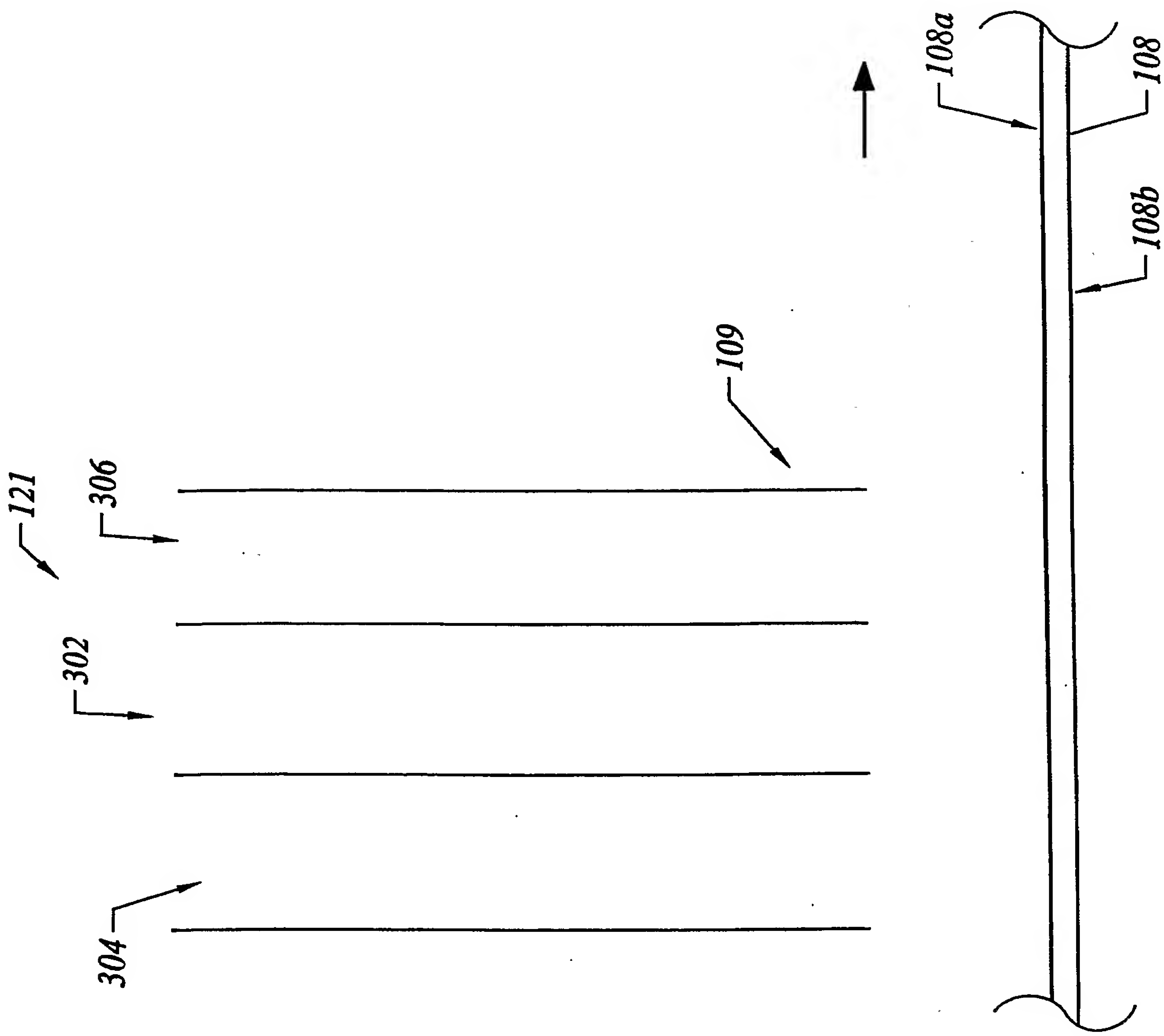


FIG. 6C

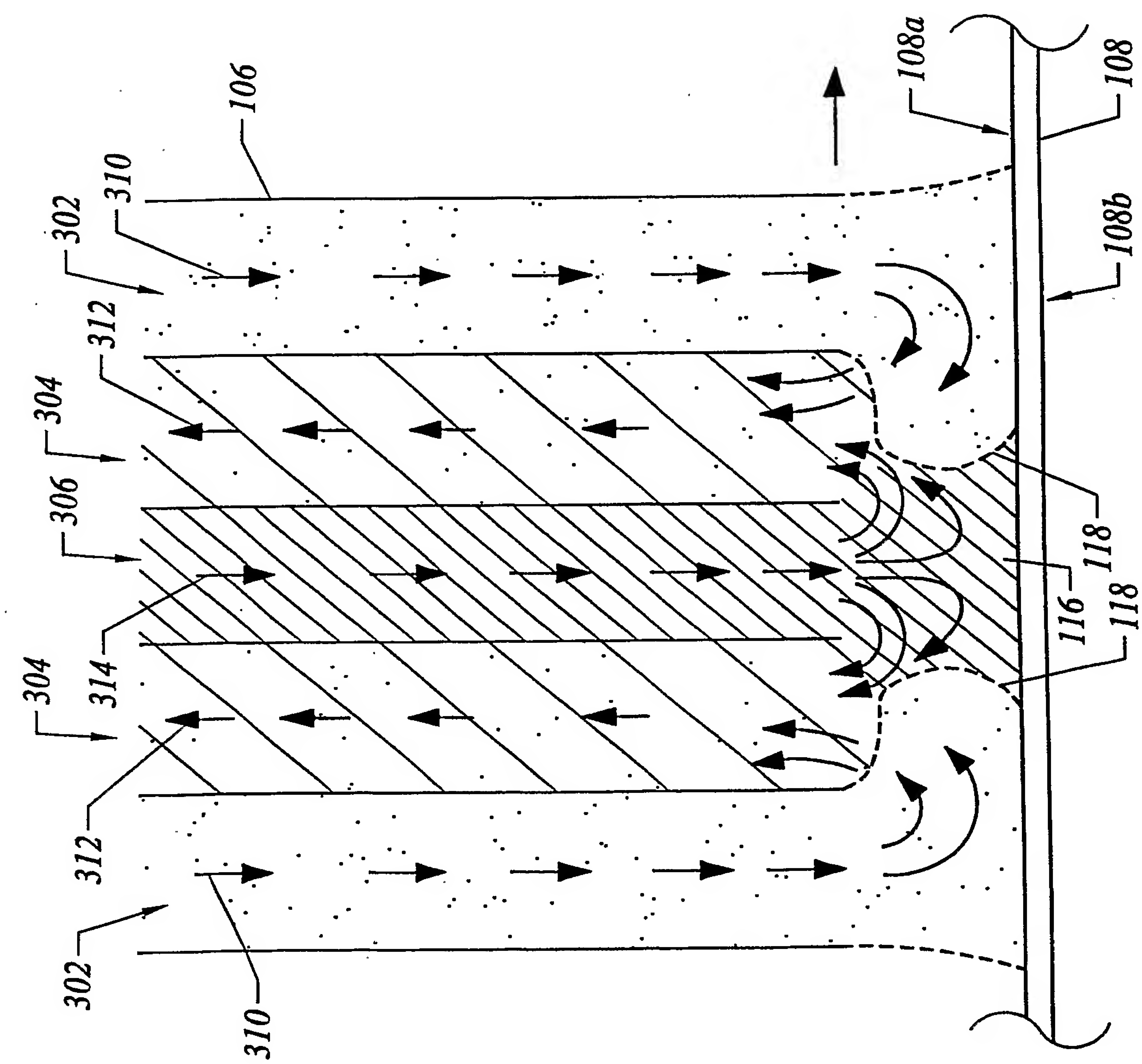

106
310
302
312
304
306
304
314
312
302
310
108a
108
108b
118
116
118

FIG. 6D

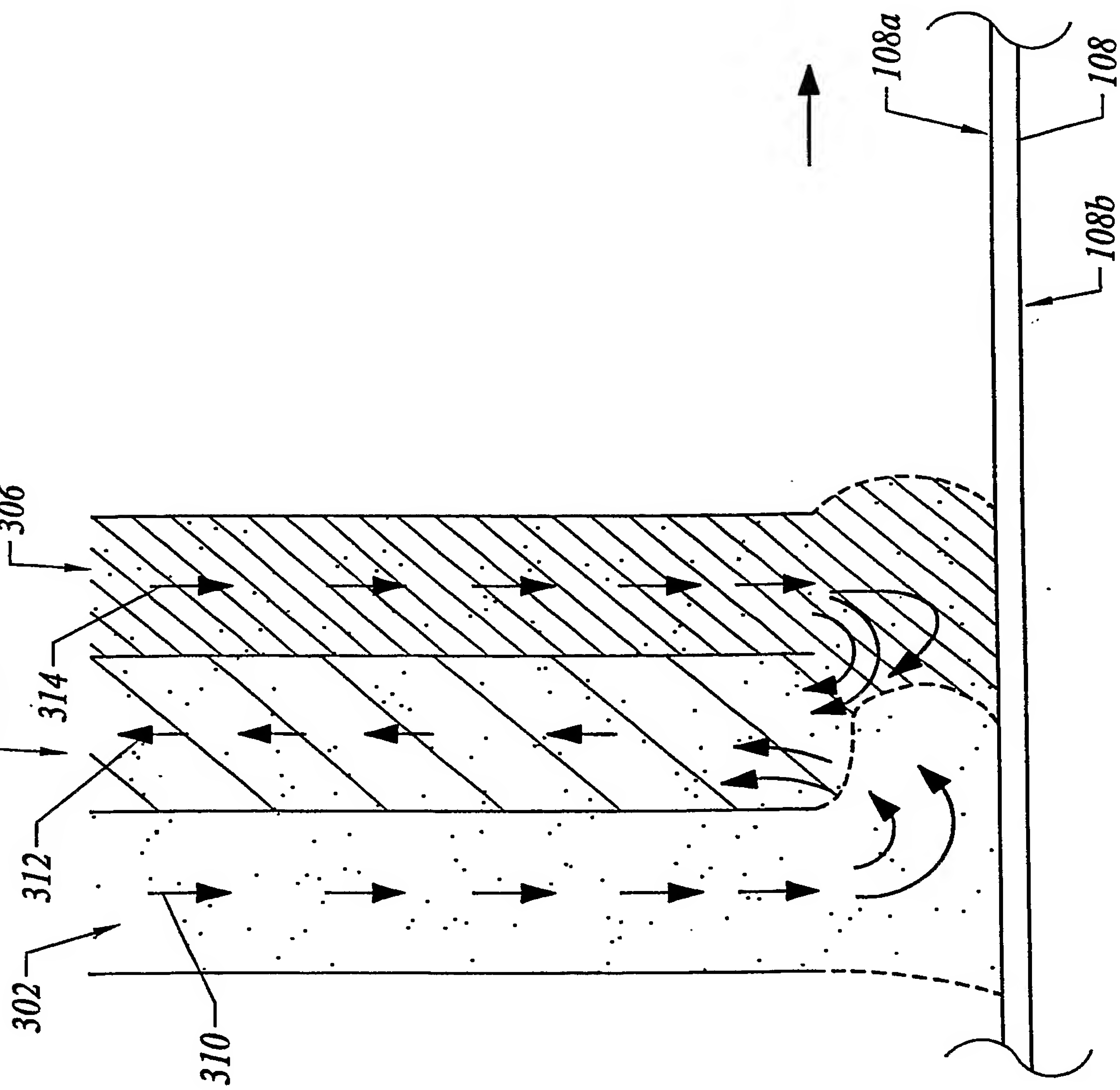


FIG. 6E

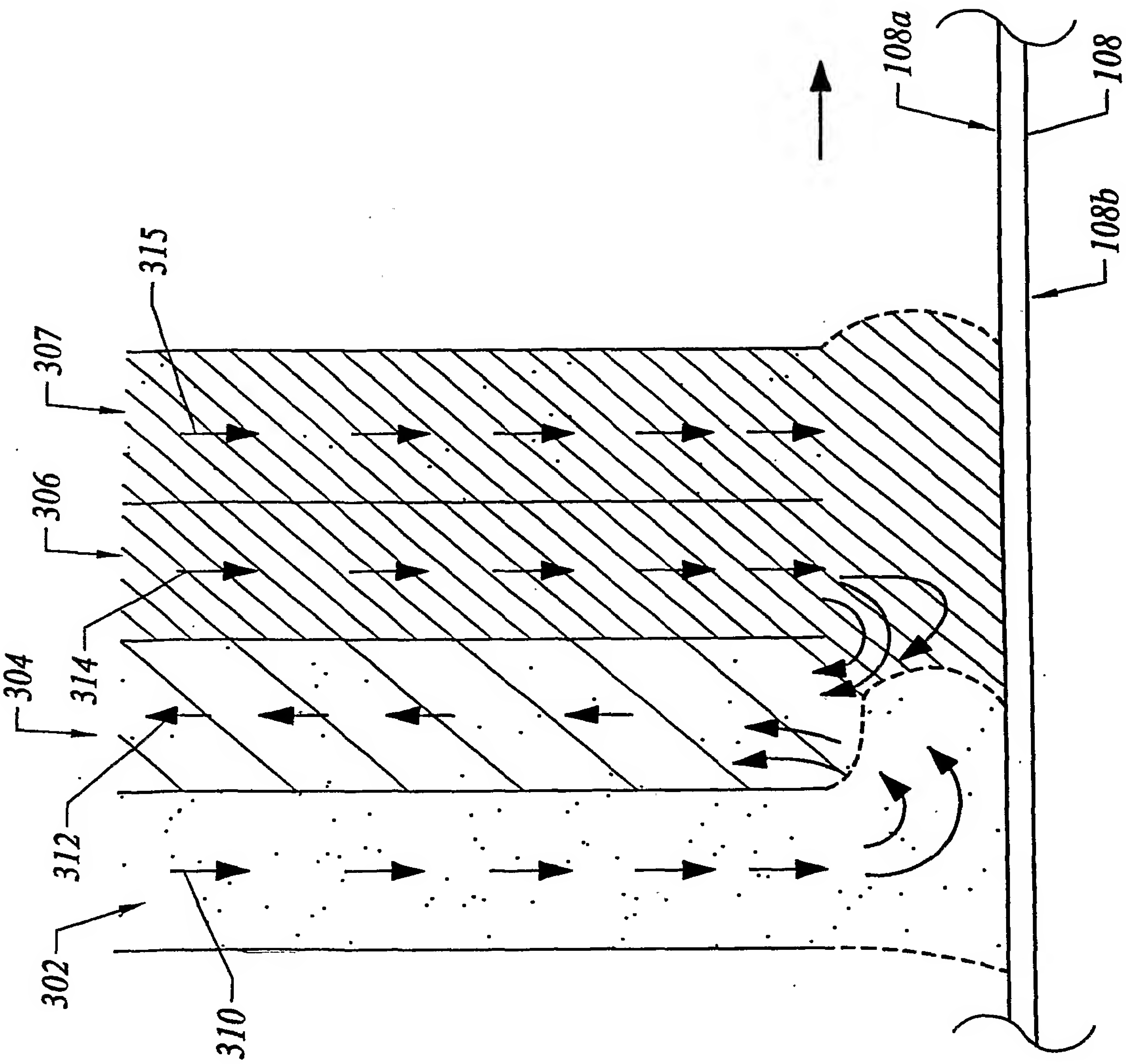


FIG. 6F

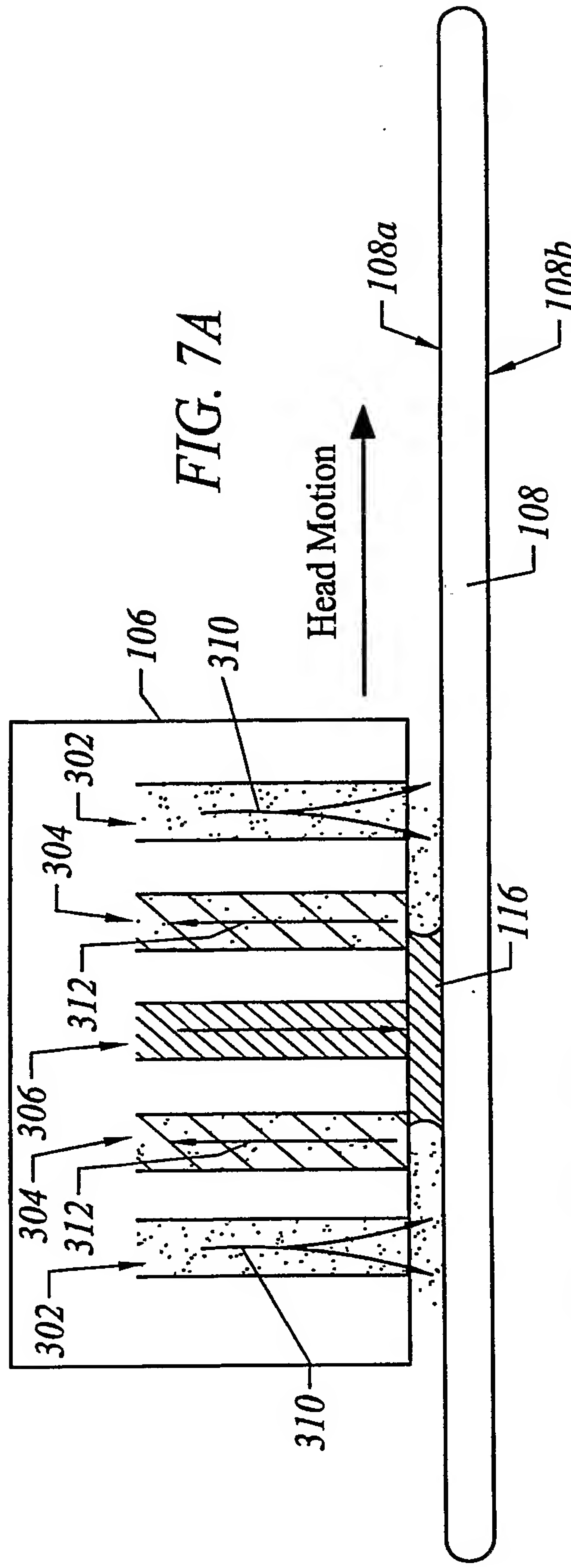

Head Motion
106
108
108a
108b
116
302
304
306
310
312

FIG. 7A

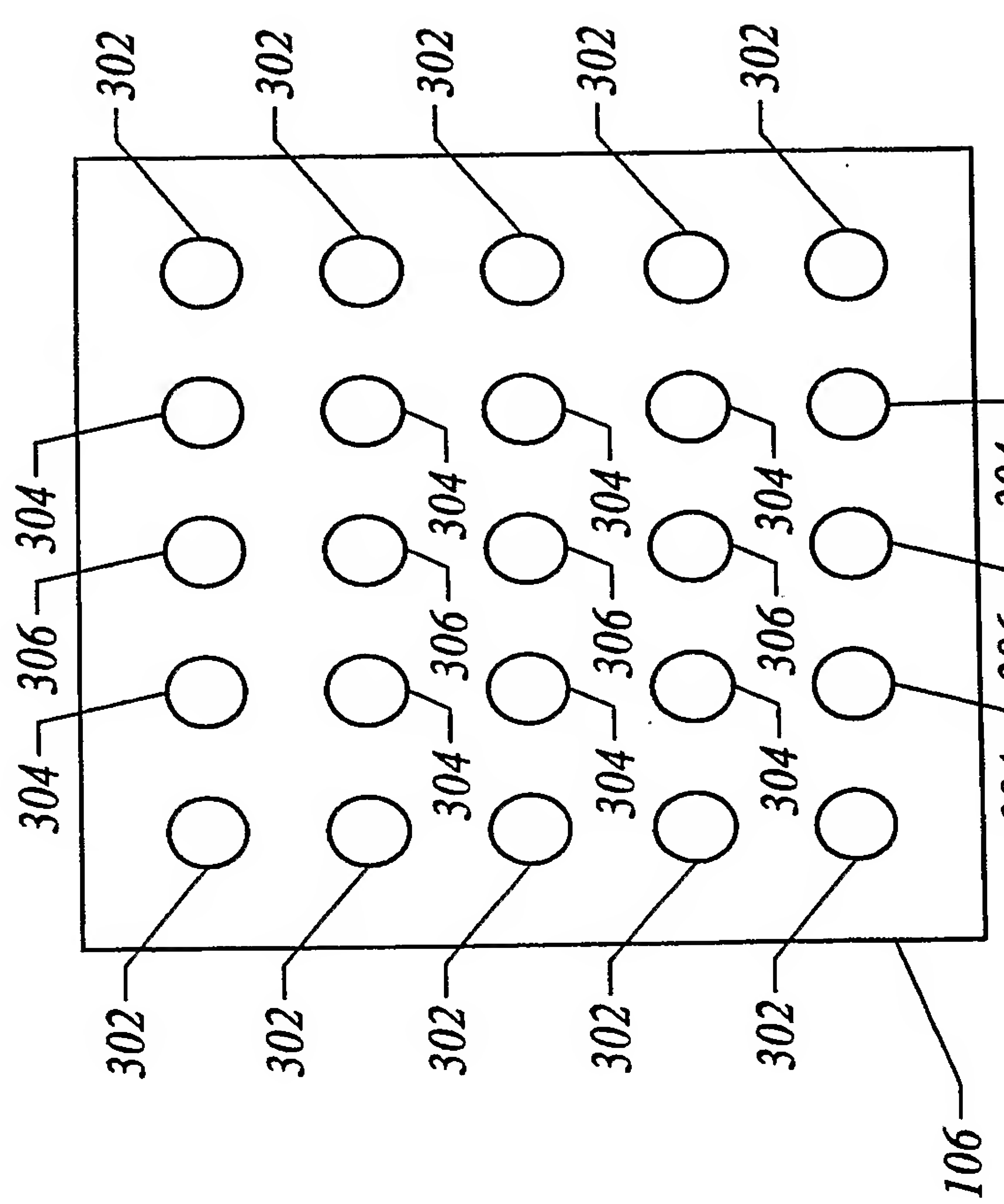

106
302
304
306

FIG. 7B

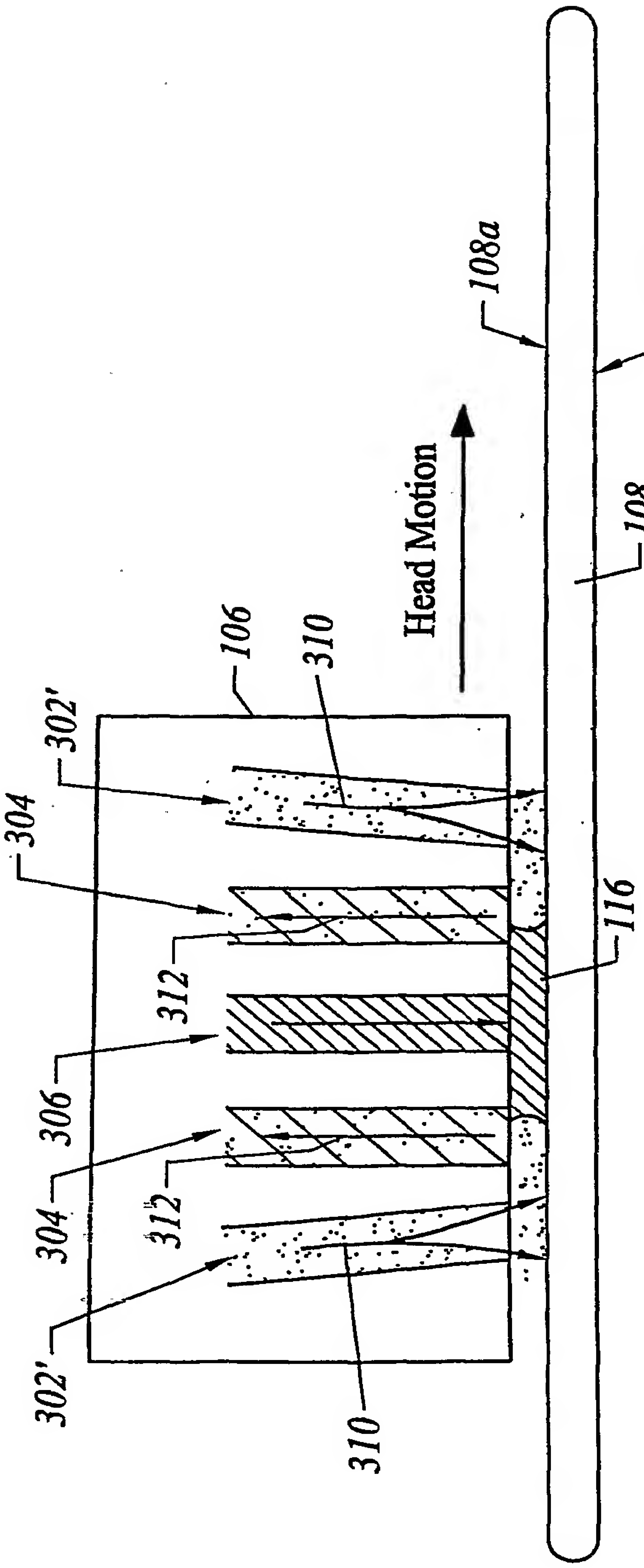

108a
108b
Head Motion
108
106
310
302'
304
116
312
306
304
312
302'
310

FIG. 7C

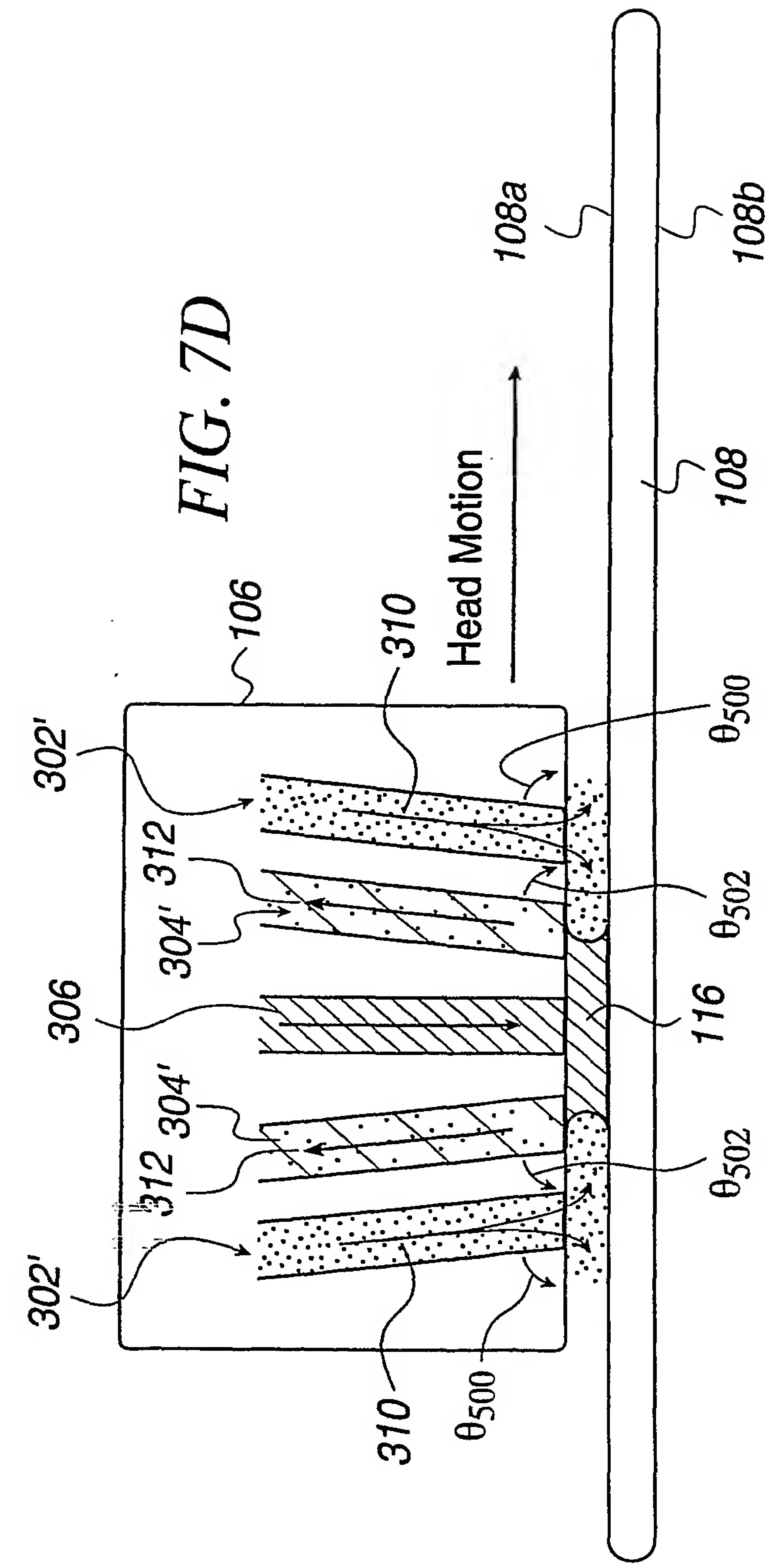

106
302'
310
312
304'
306
116
θ_{500}
θ_{502}
Head Motion
108
108a
108b

FIG. 7D

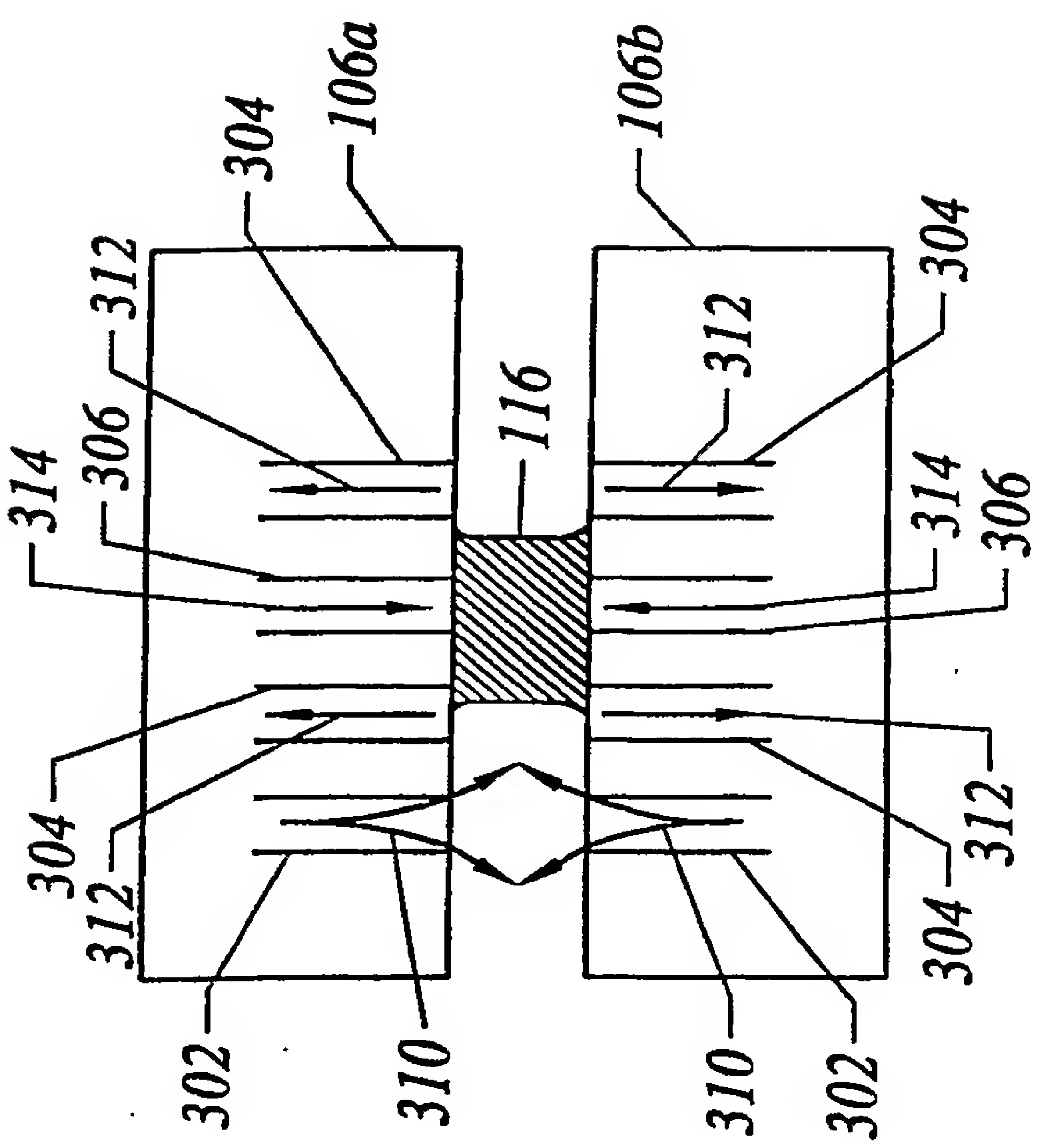

106a
304
312
306
314
116
106b
304
312
314
306
304
312
302
310
310
302
304
312

FIG. 8A

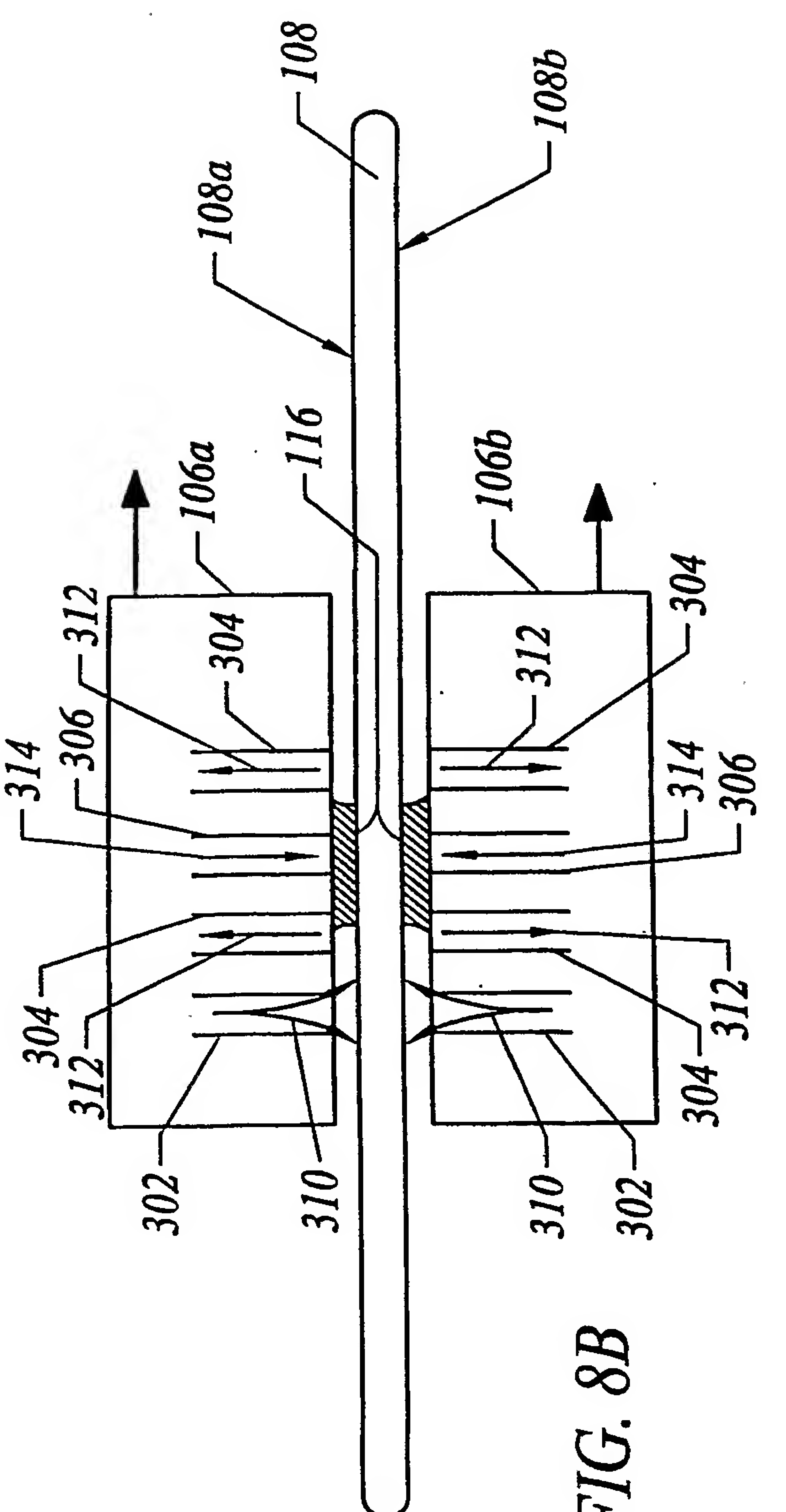

108
108b
108a
116
106a
106b
312
304
306
314
304
312
314
306
304
312
302
310
310
302
304
312

FIG. 8B

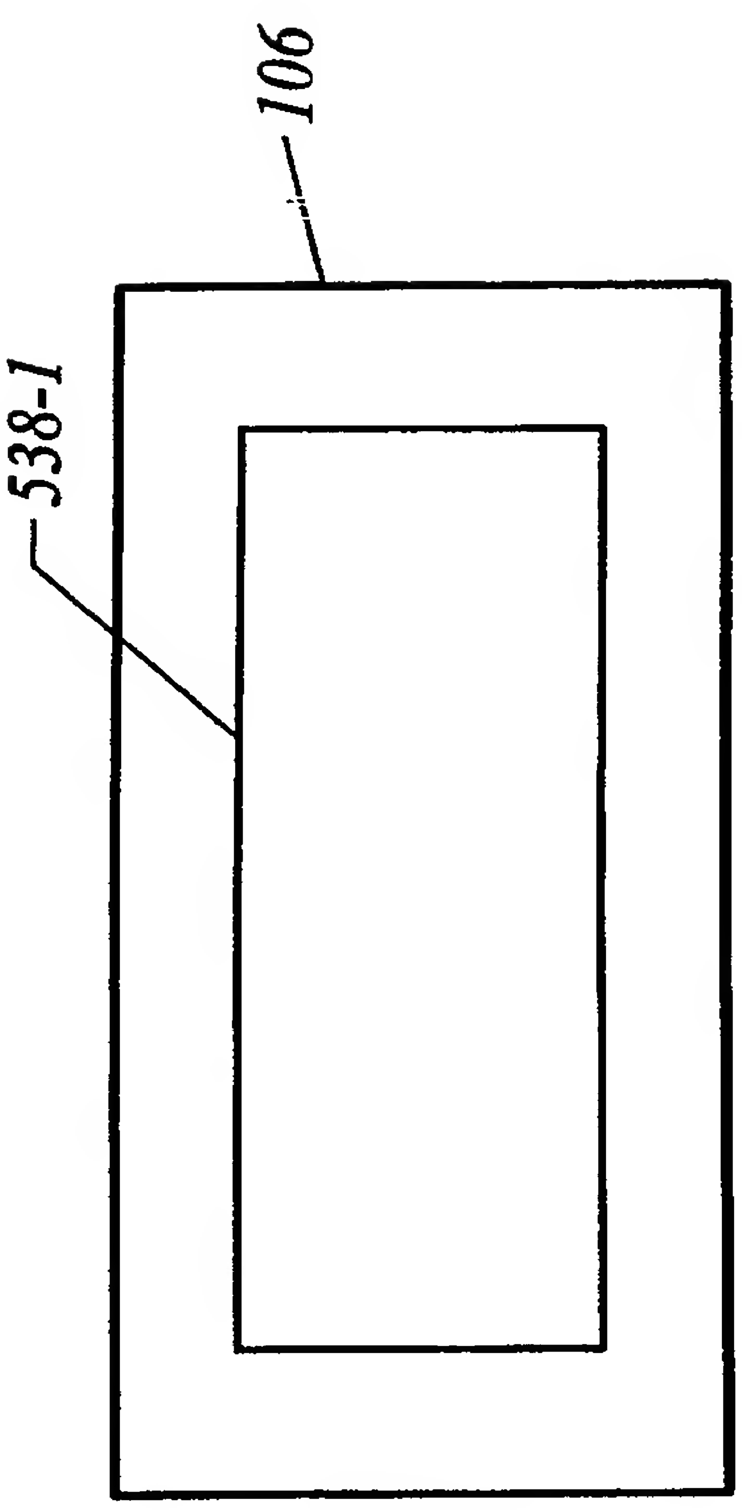


FIG. 9A

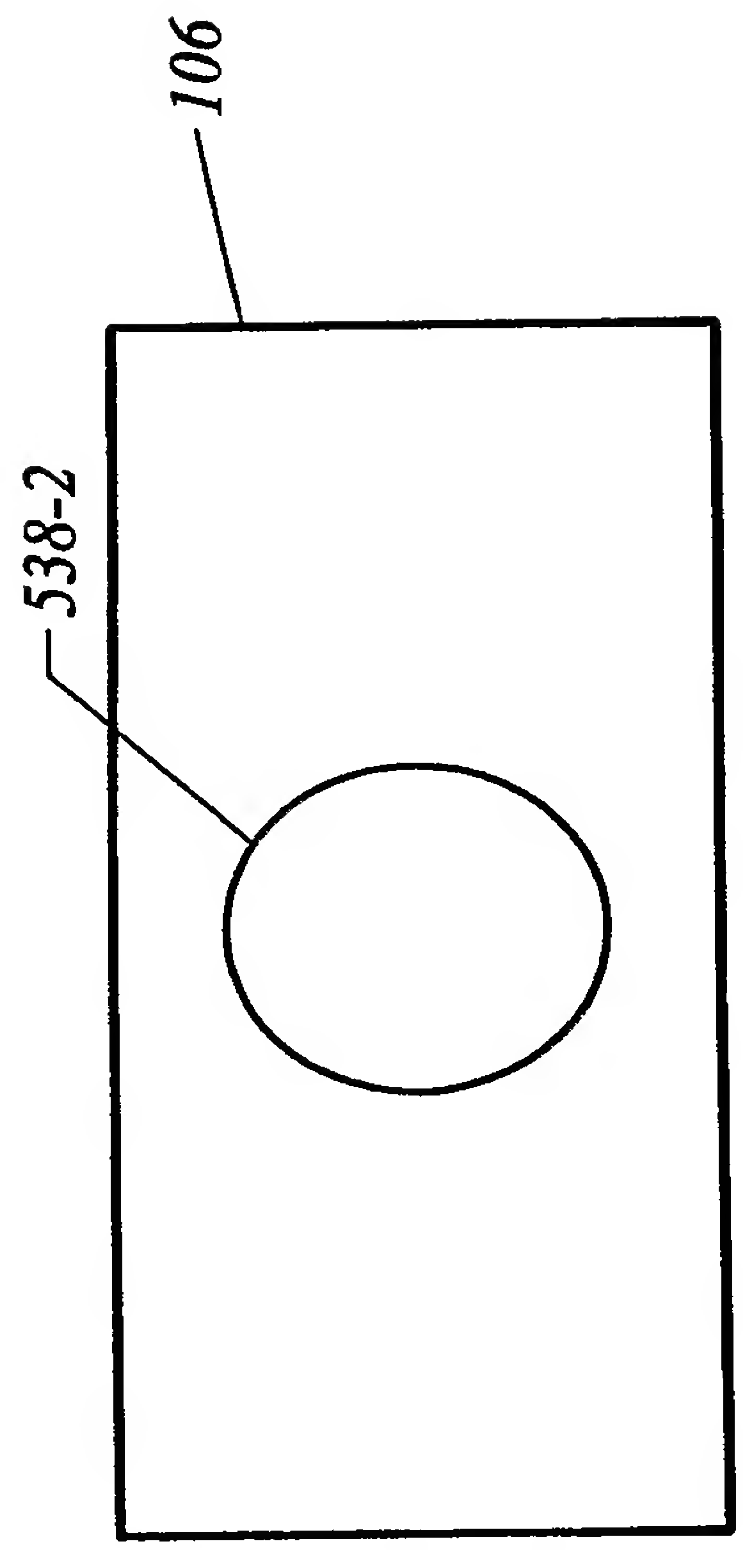


FIG. 9B

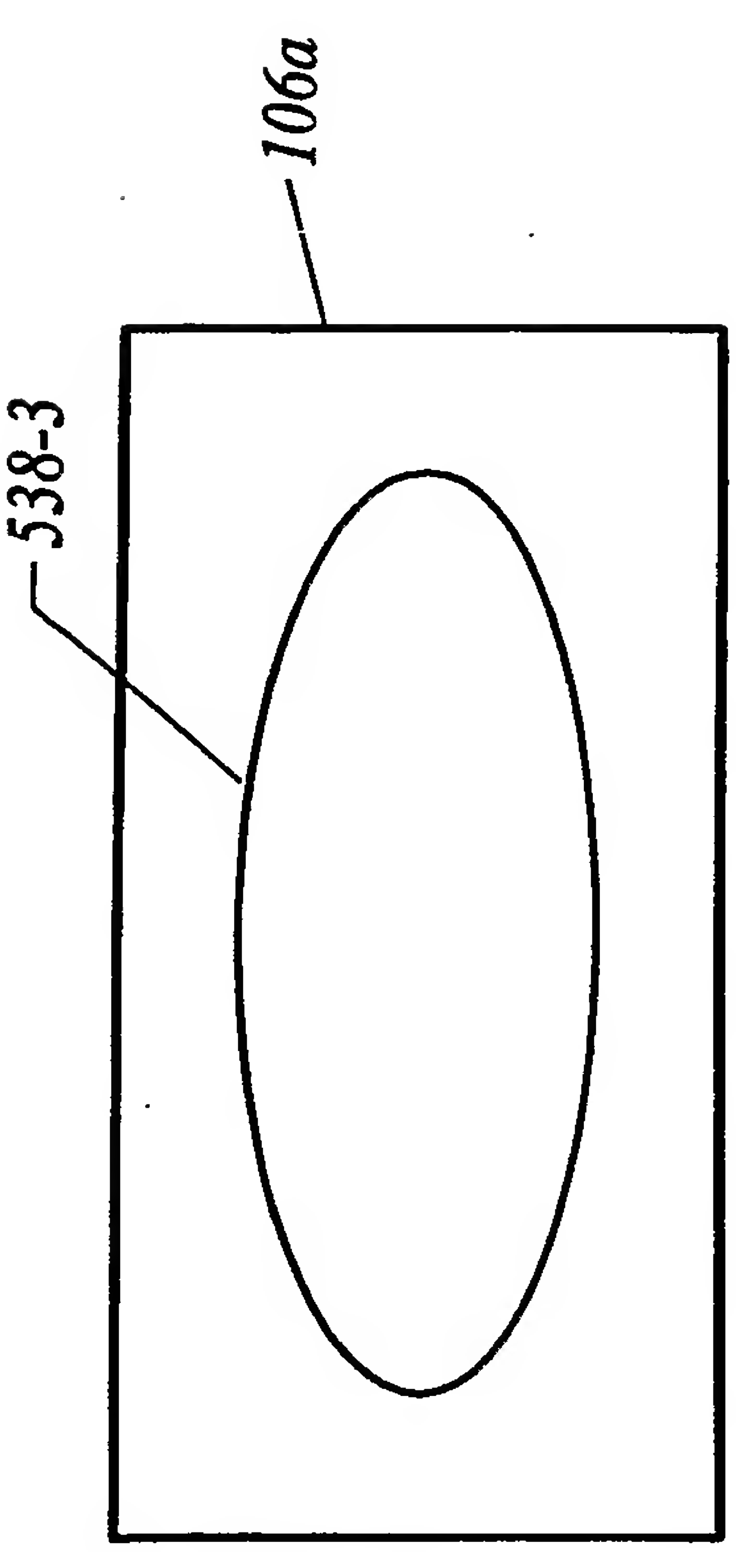


FIG. 9C

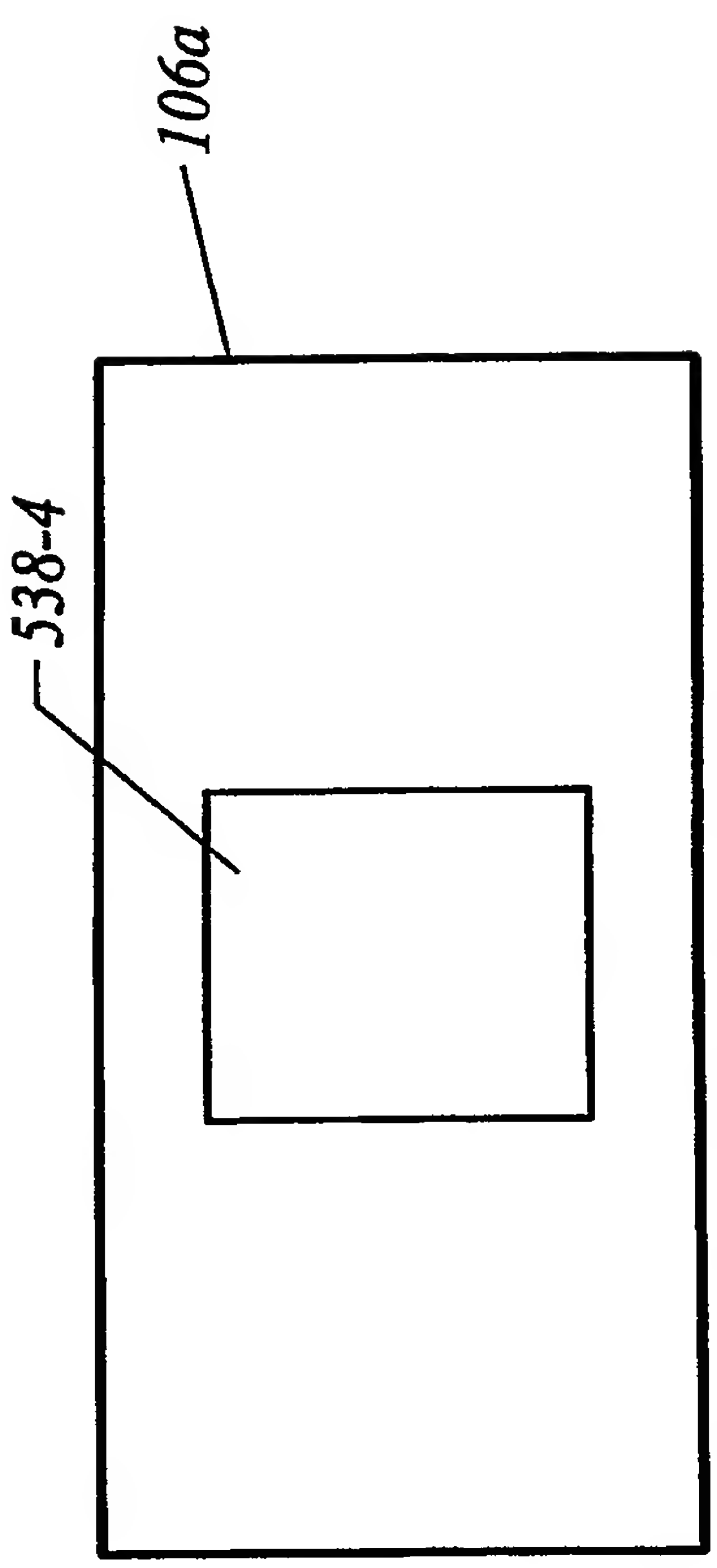


FIG. 9D

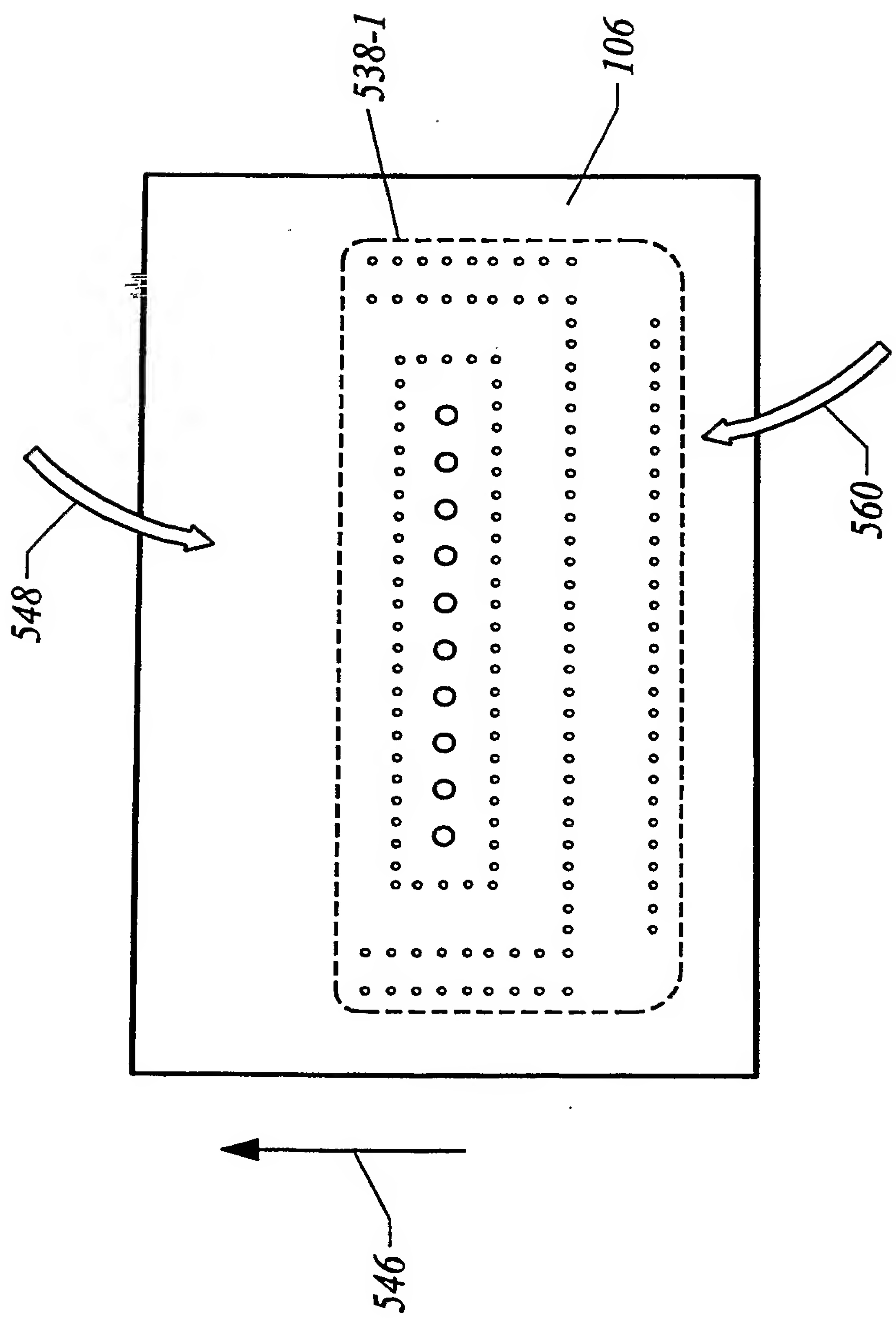


FIG. 10A

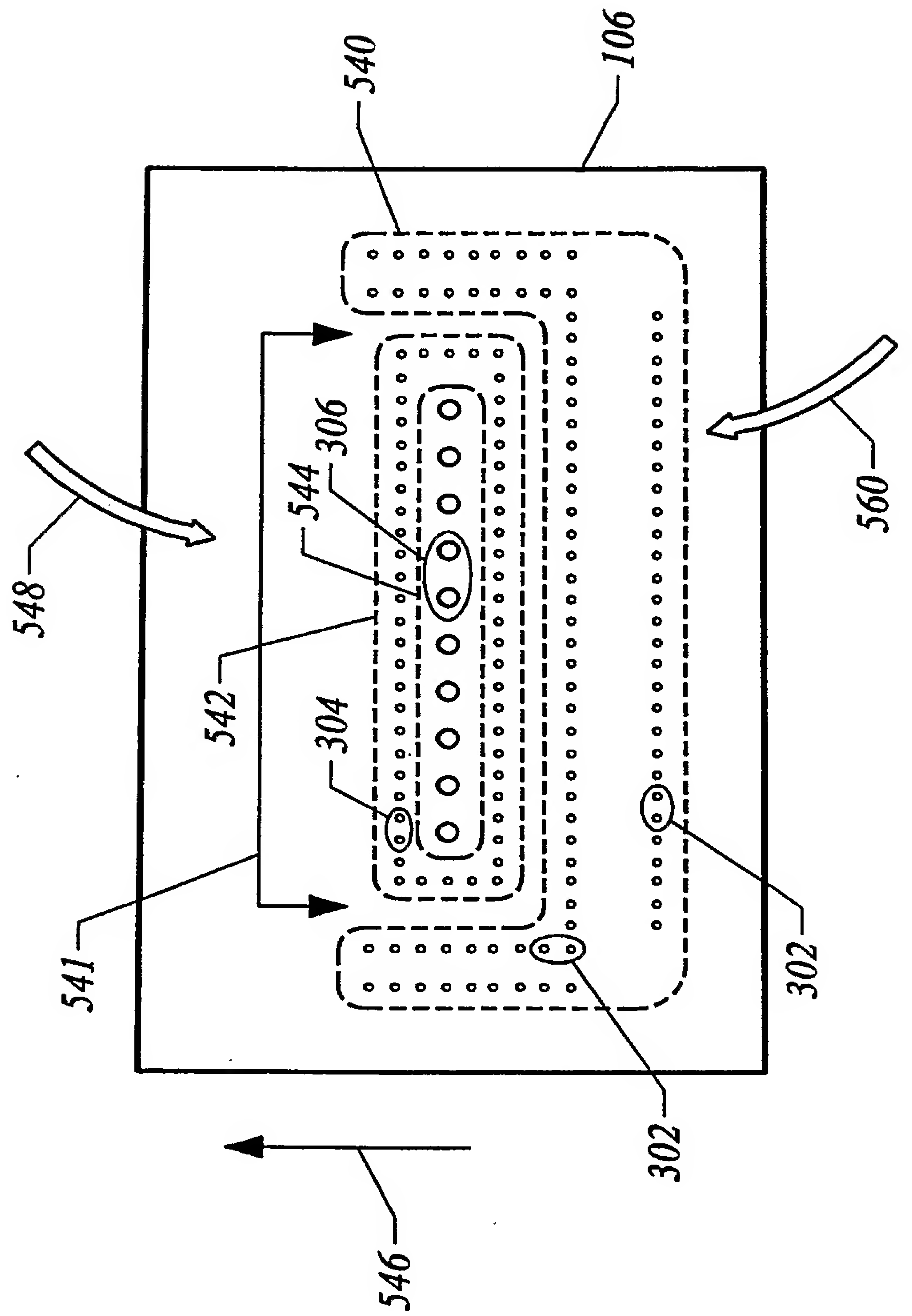


FIG. 10B

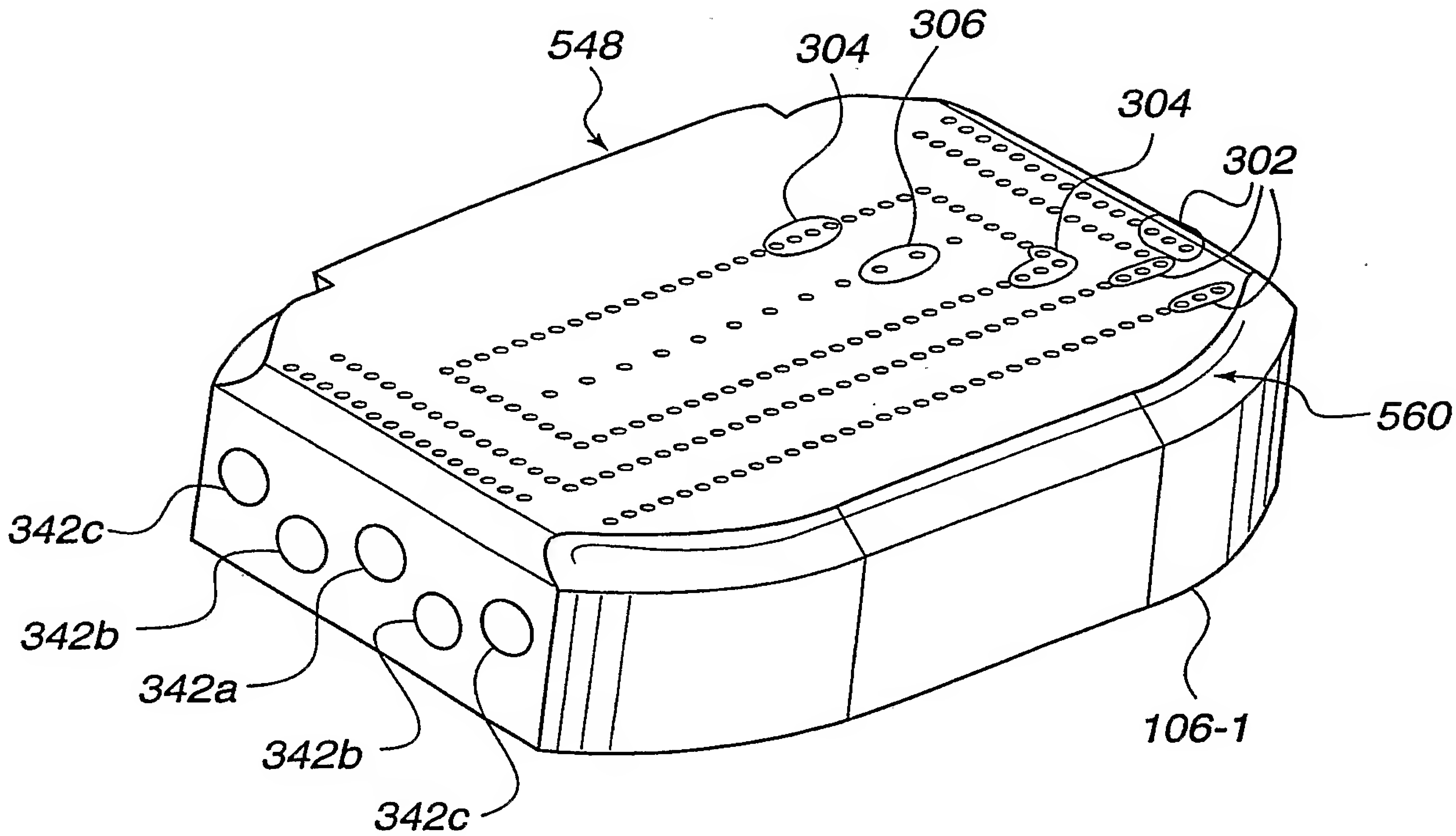


FIG. 11A

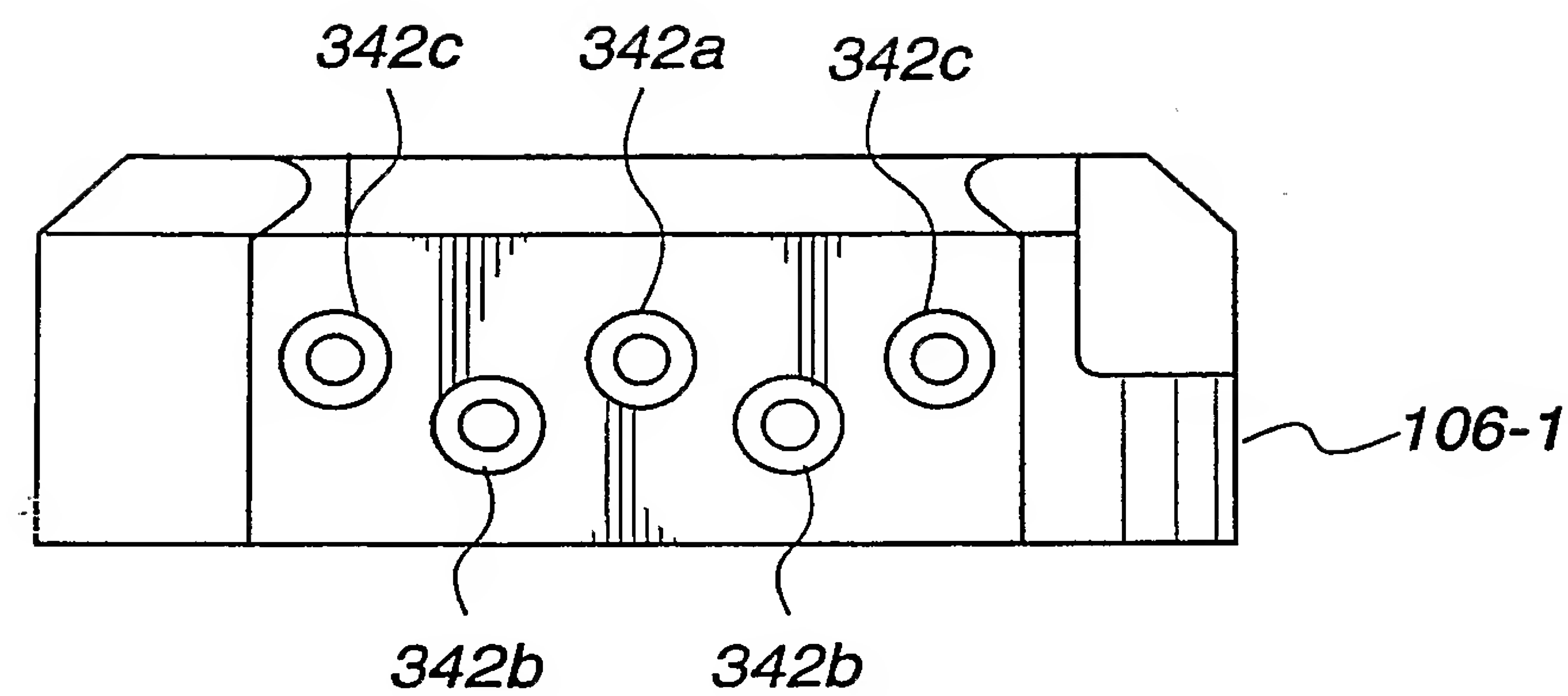


FIG. 11B

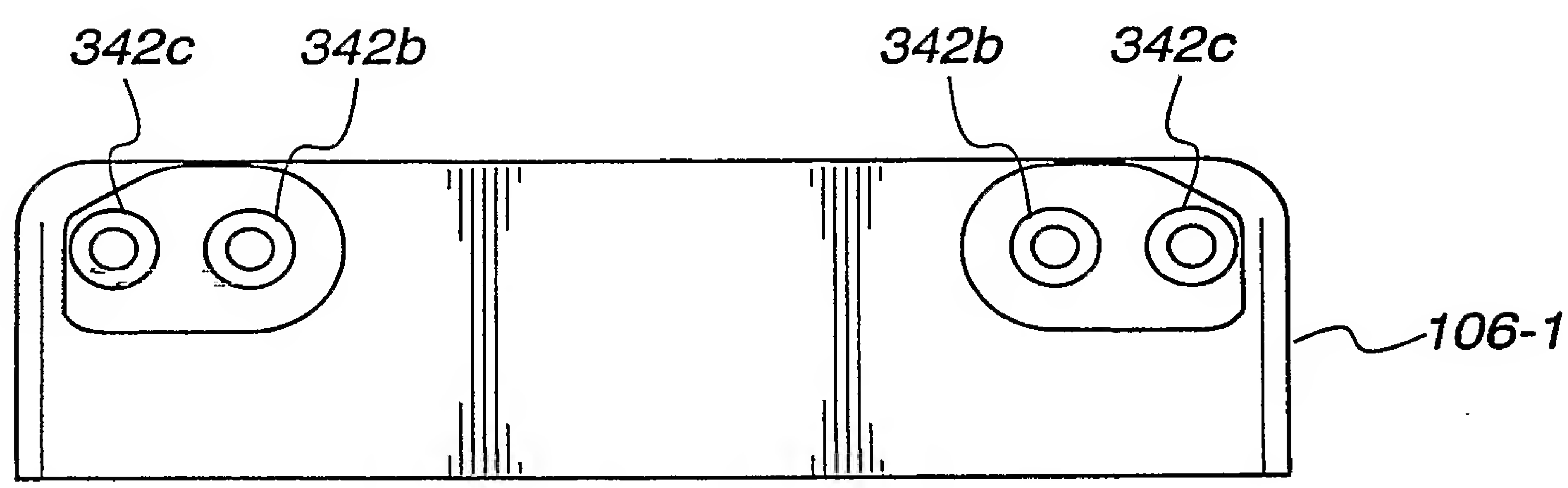


FIG. 11C

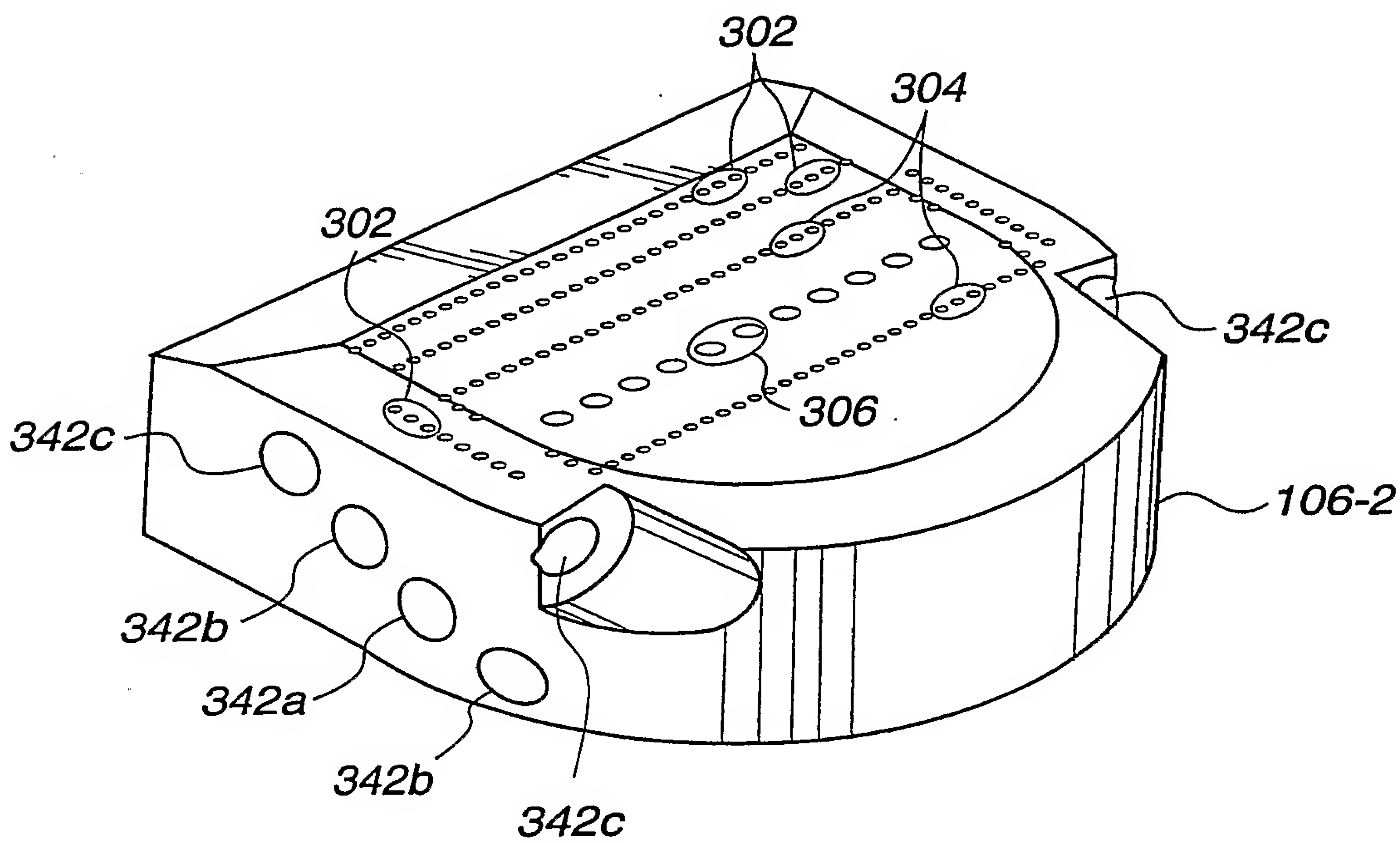


FIG. 12A

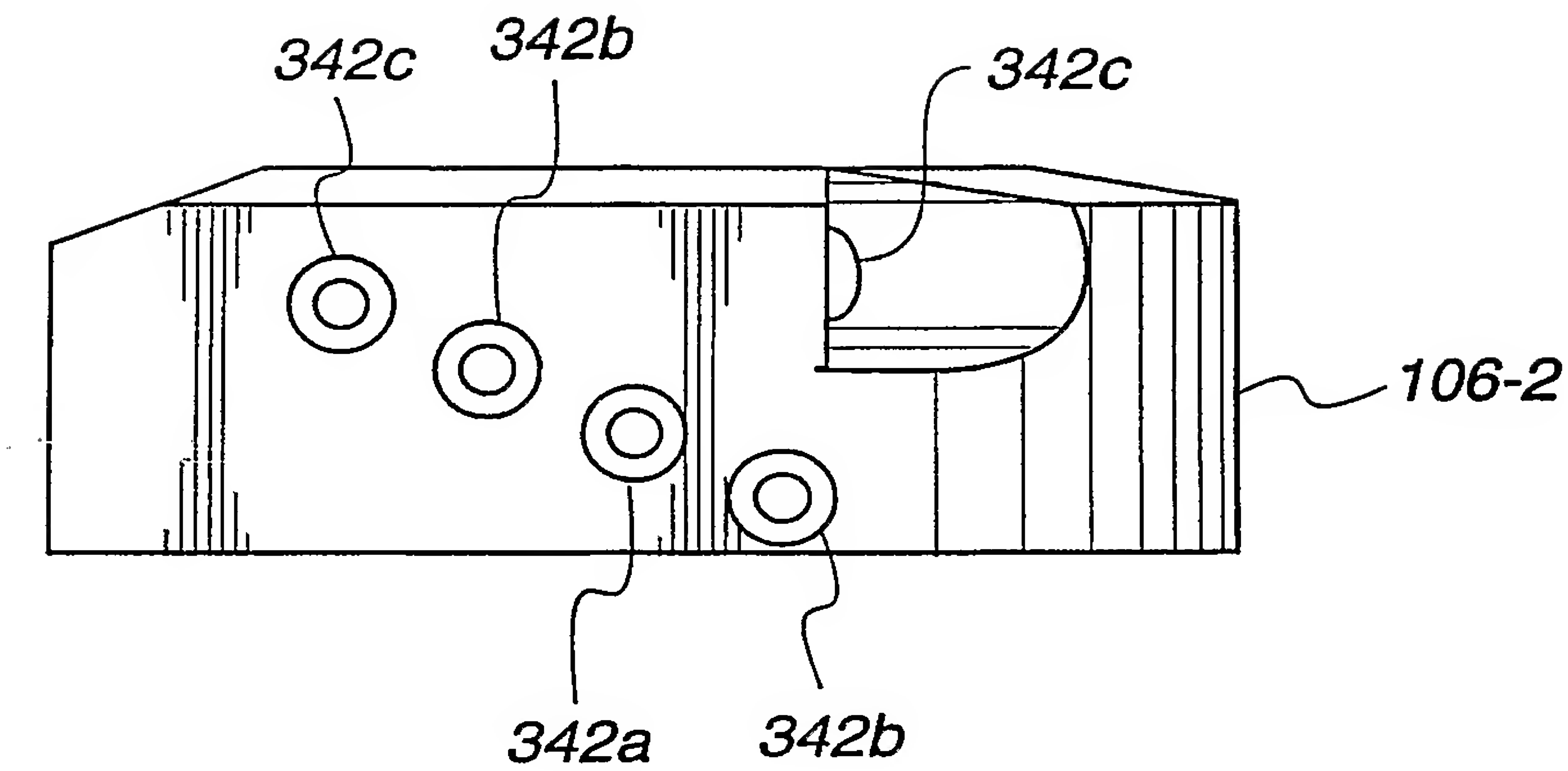


FIG. 12B

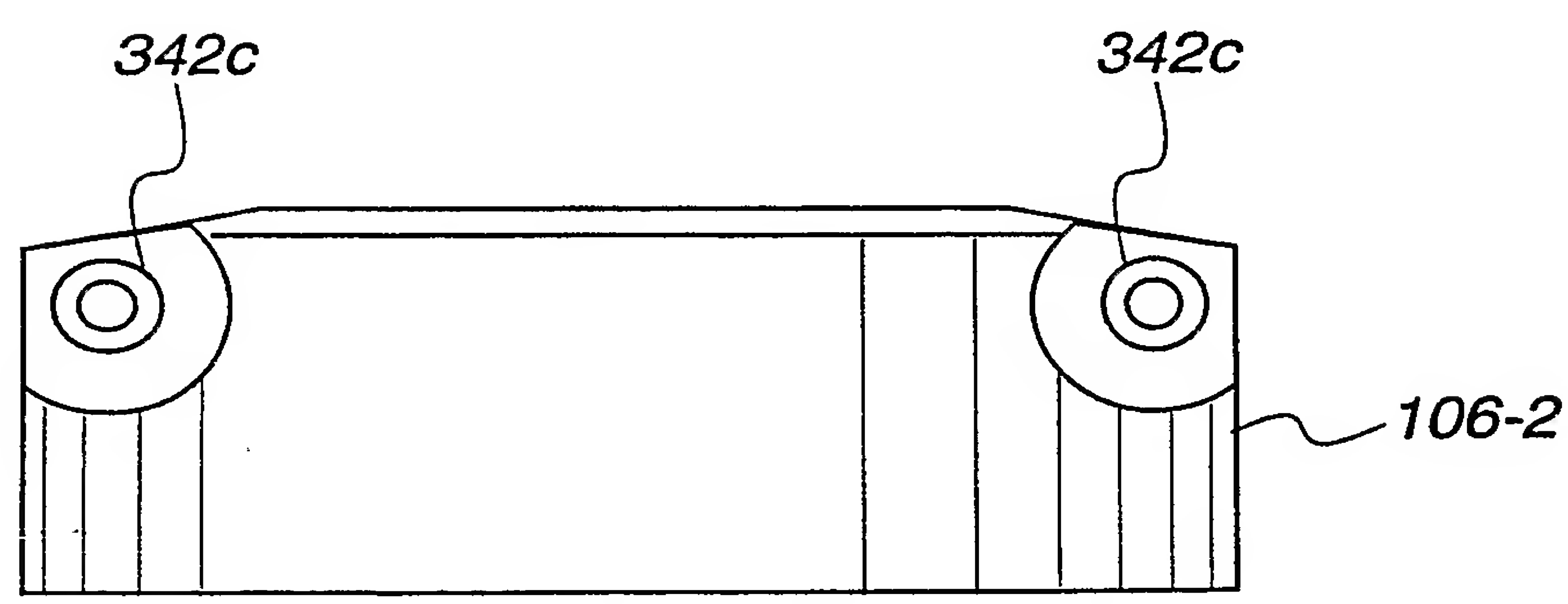


FIG. 12C

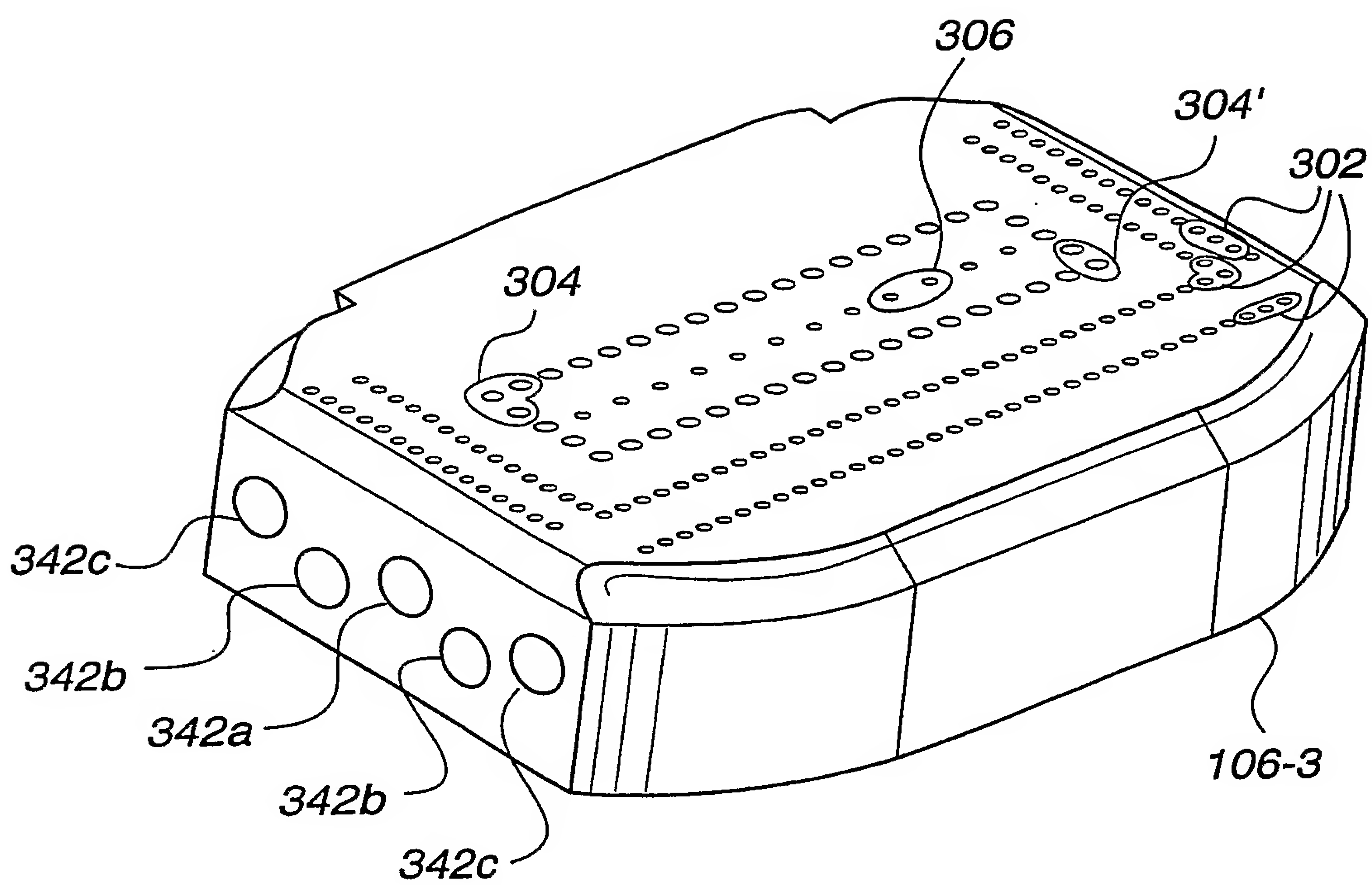


FIG. 13A

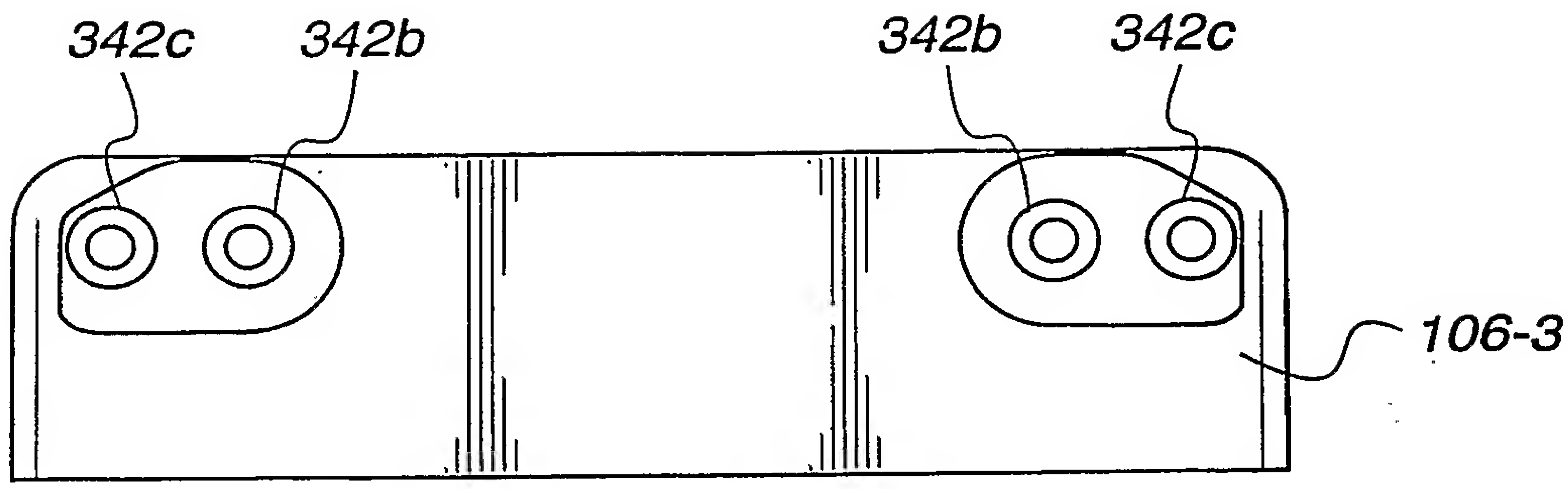


FIG. 13B

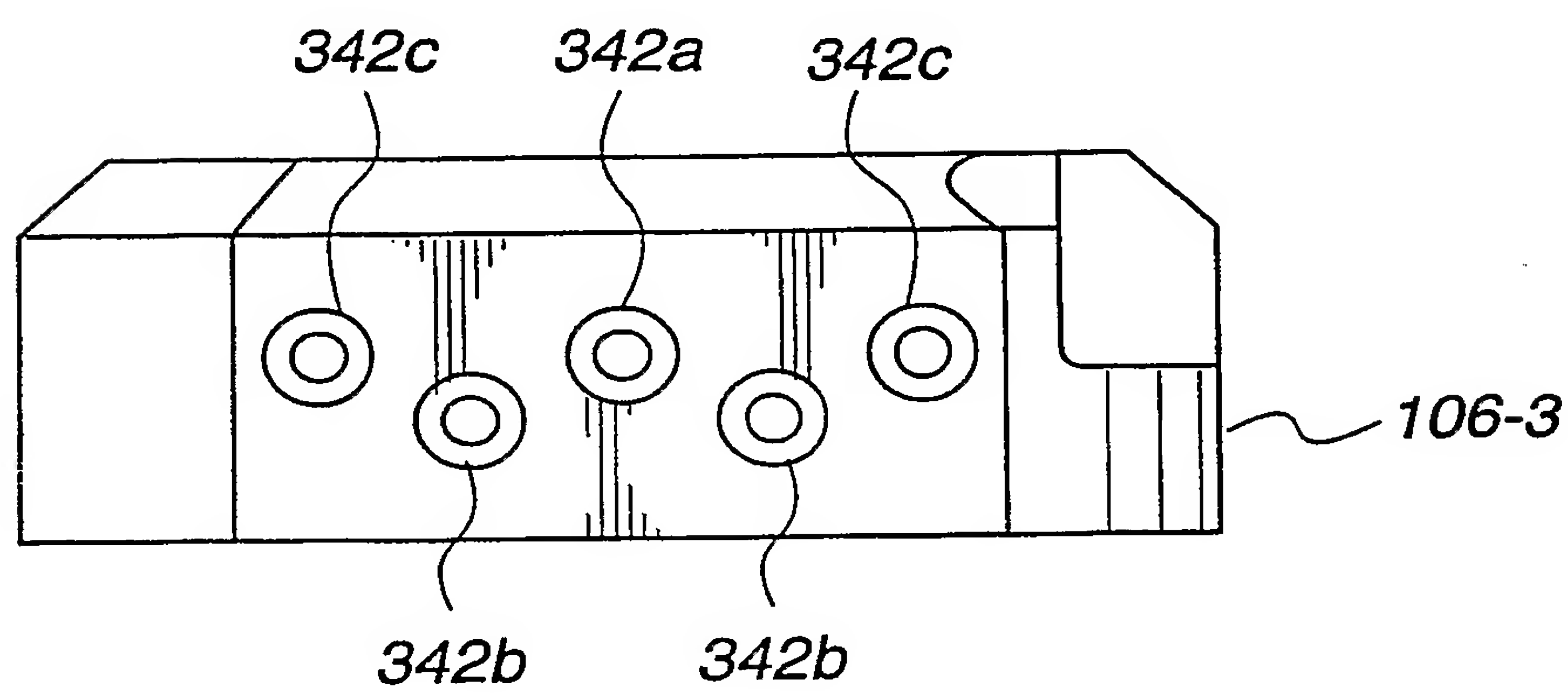


FIG. 13C

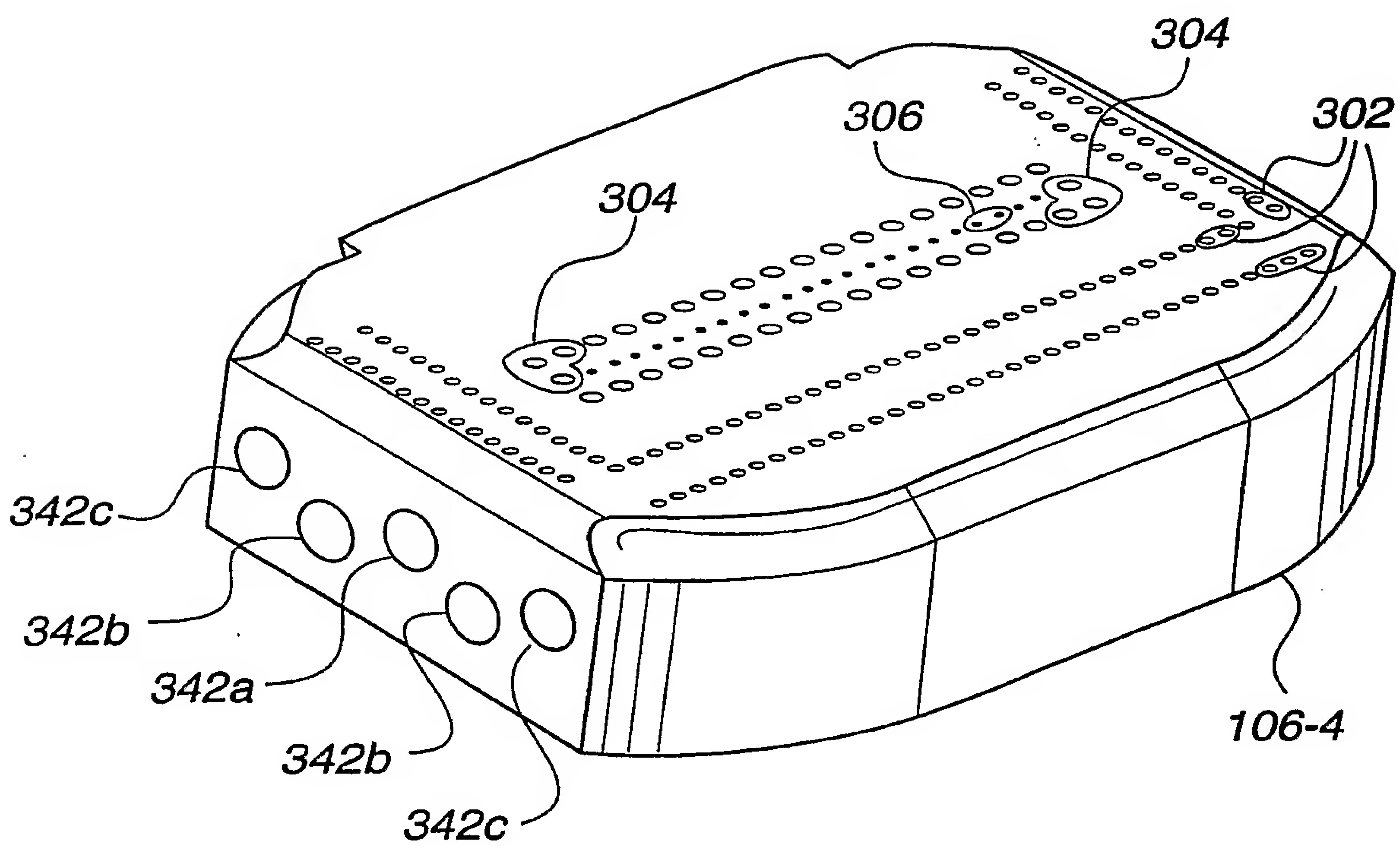


FIG. 14A

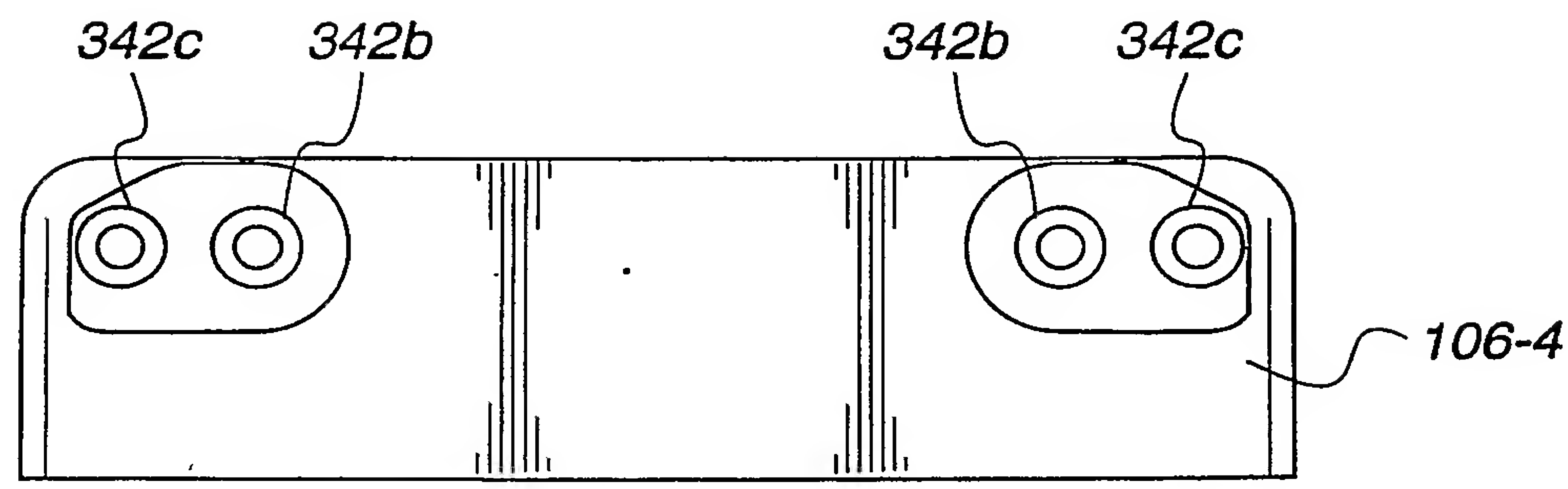


FIG. 14B

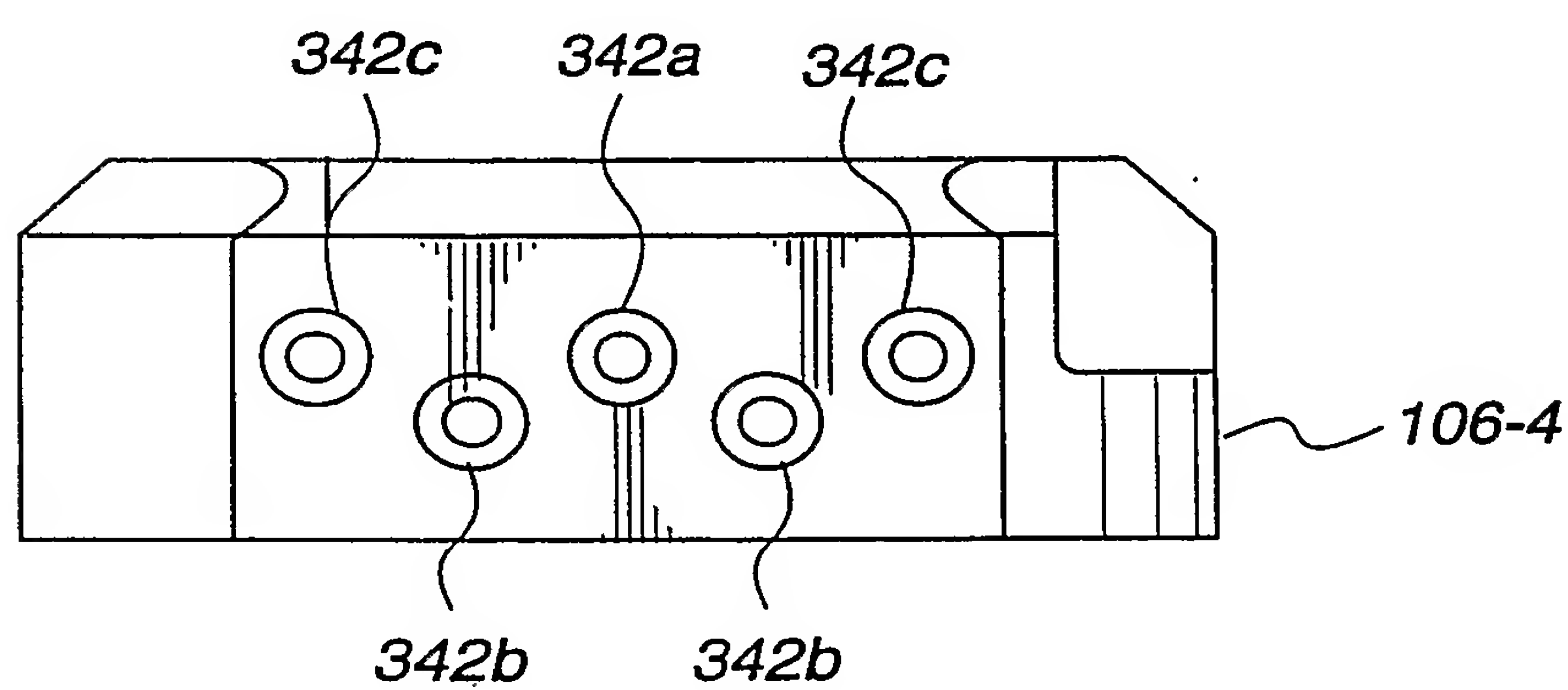


FIG. 14C

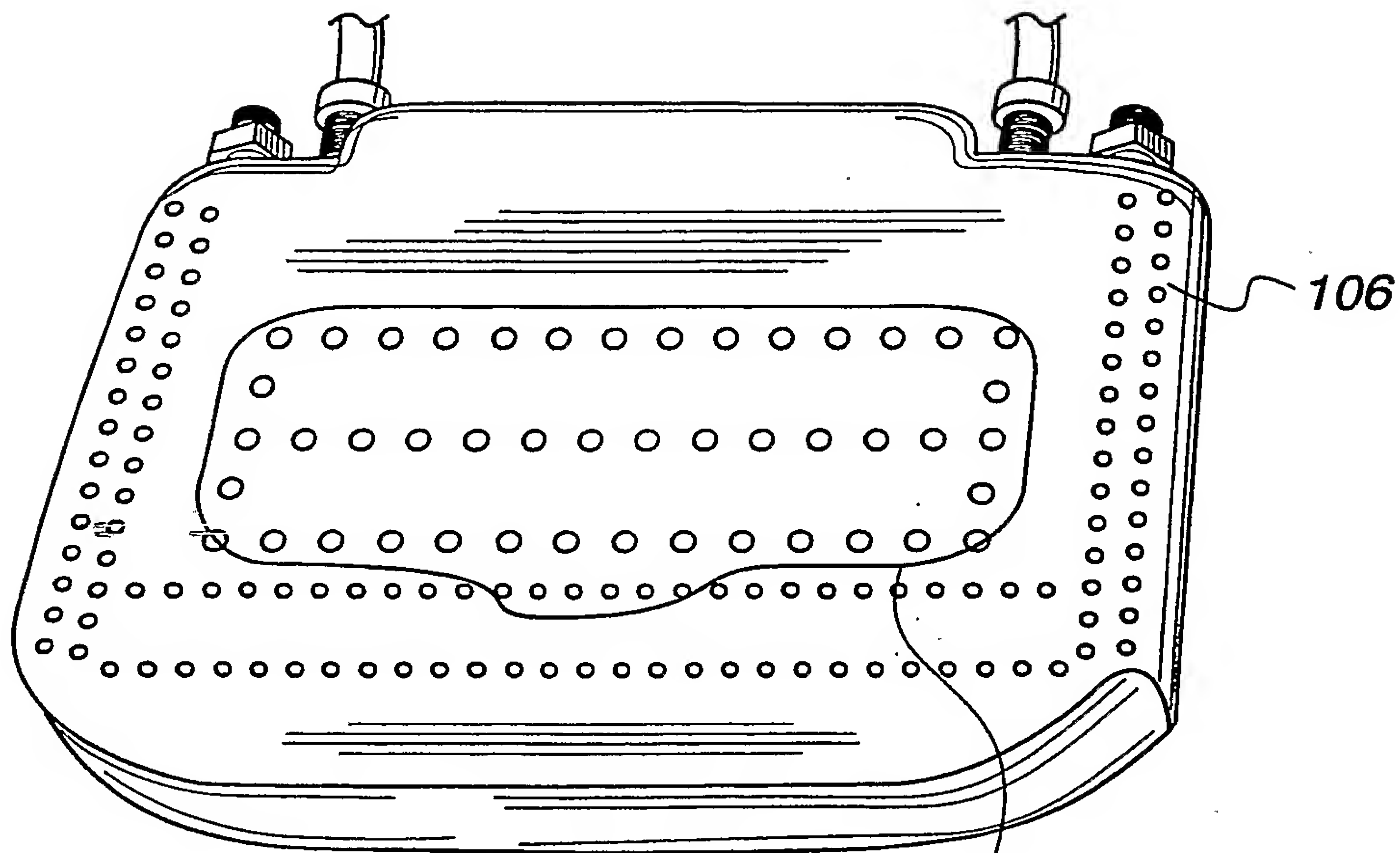


FIG. 15A

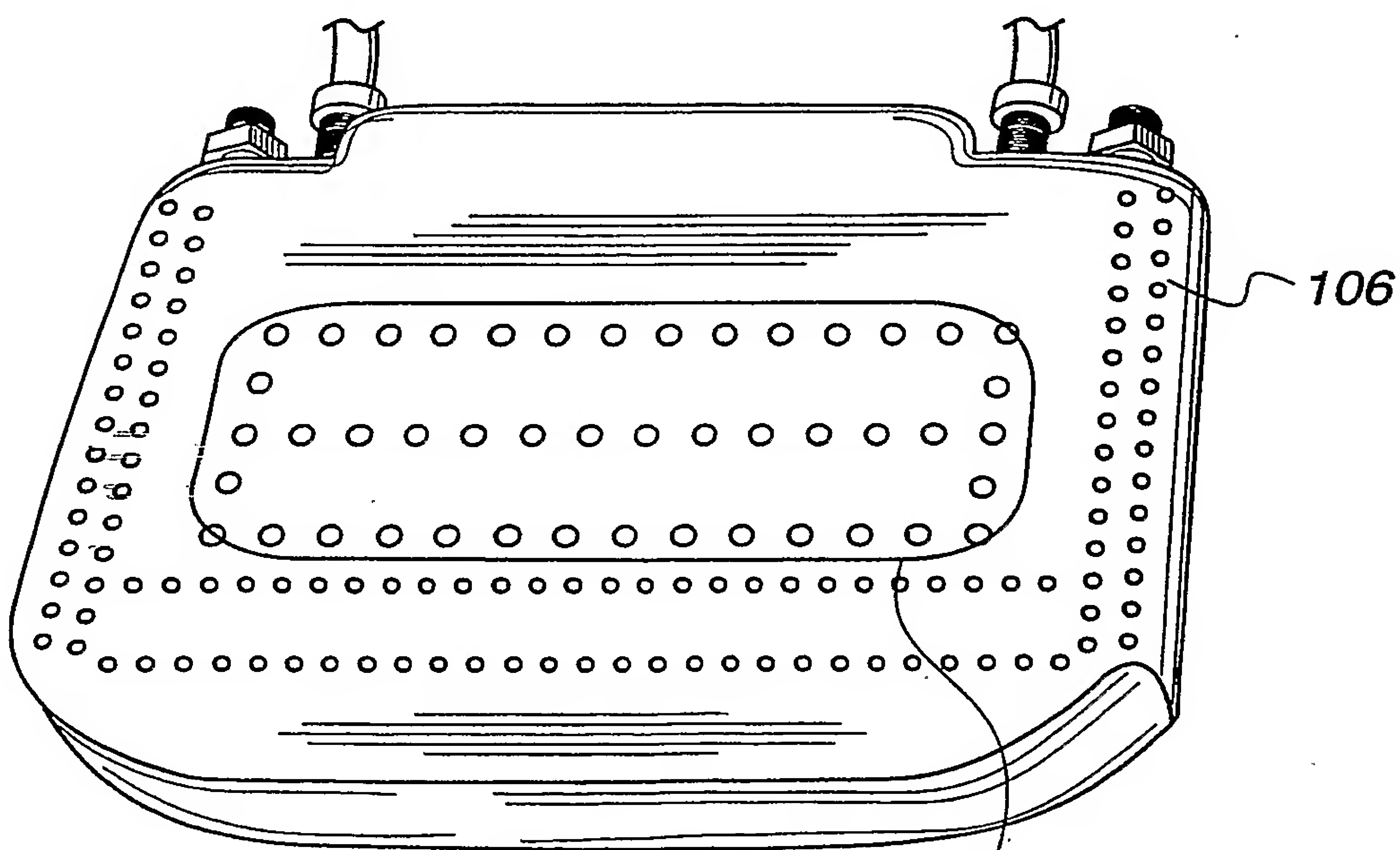


FIG. 15B

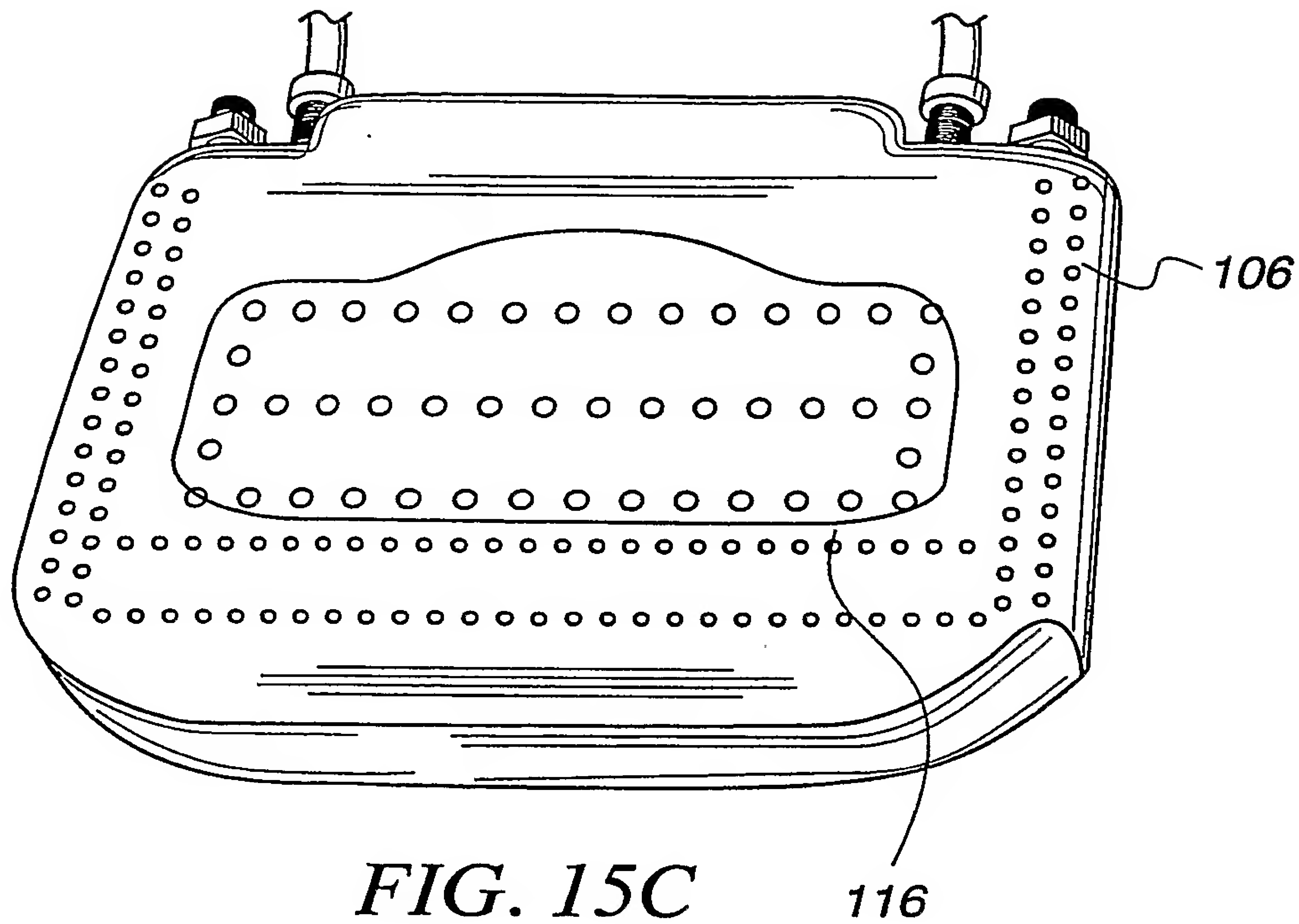


FIG. 15C

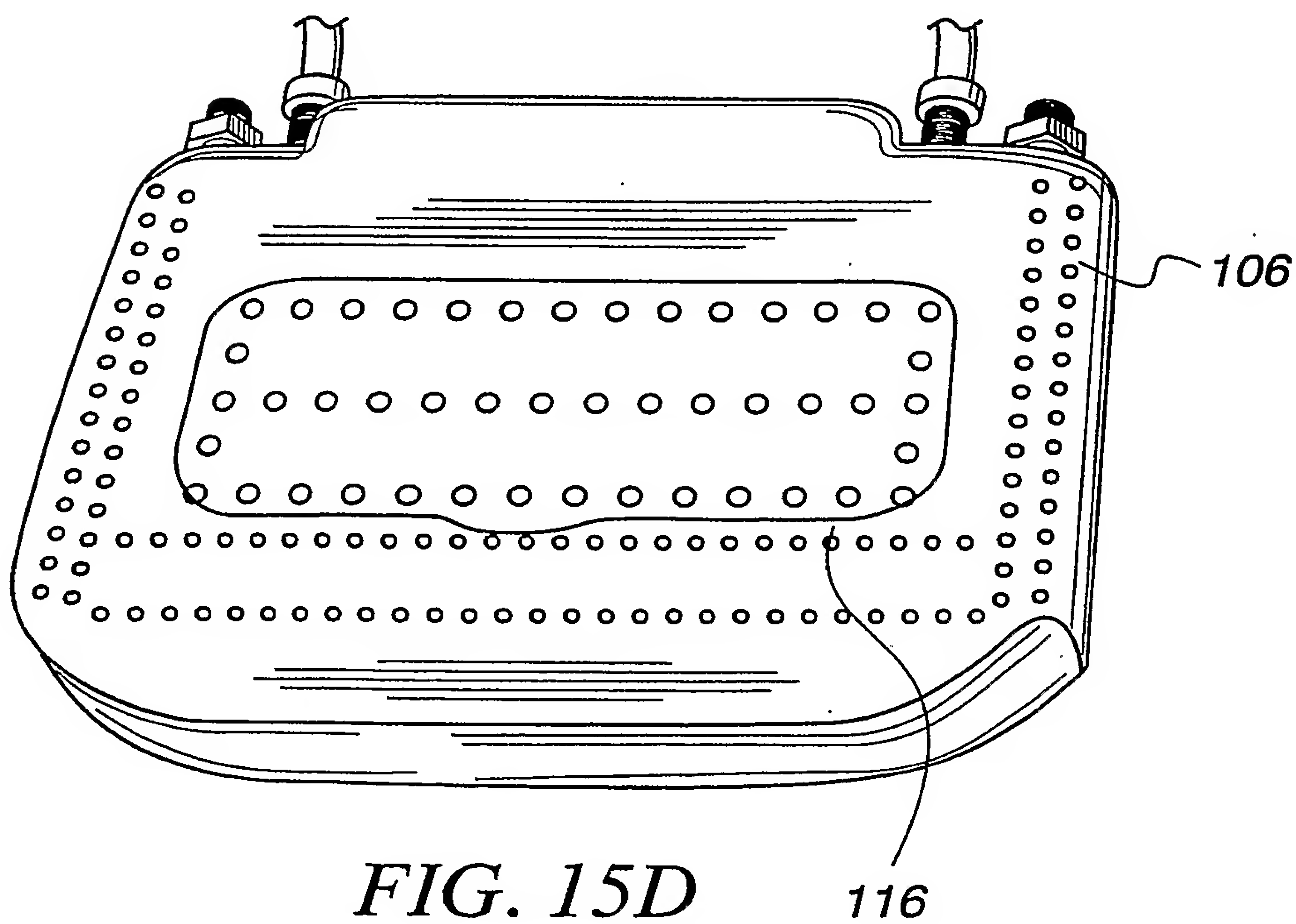


FIG. 15D

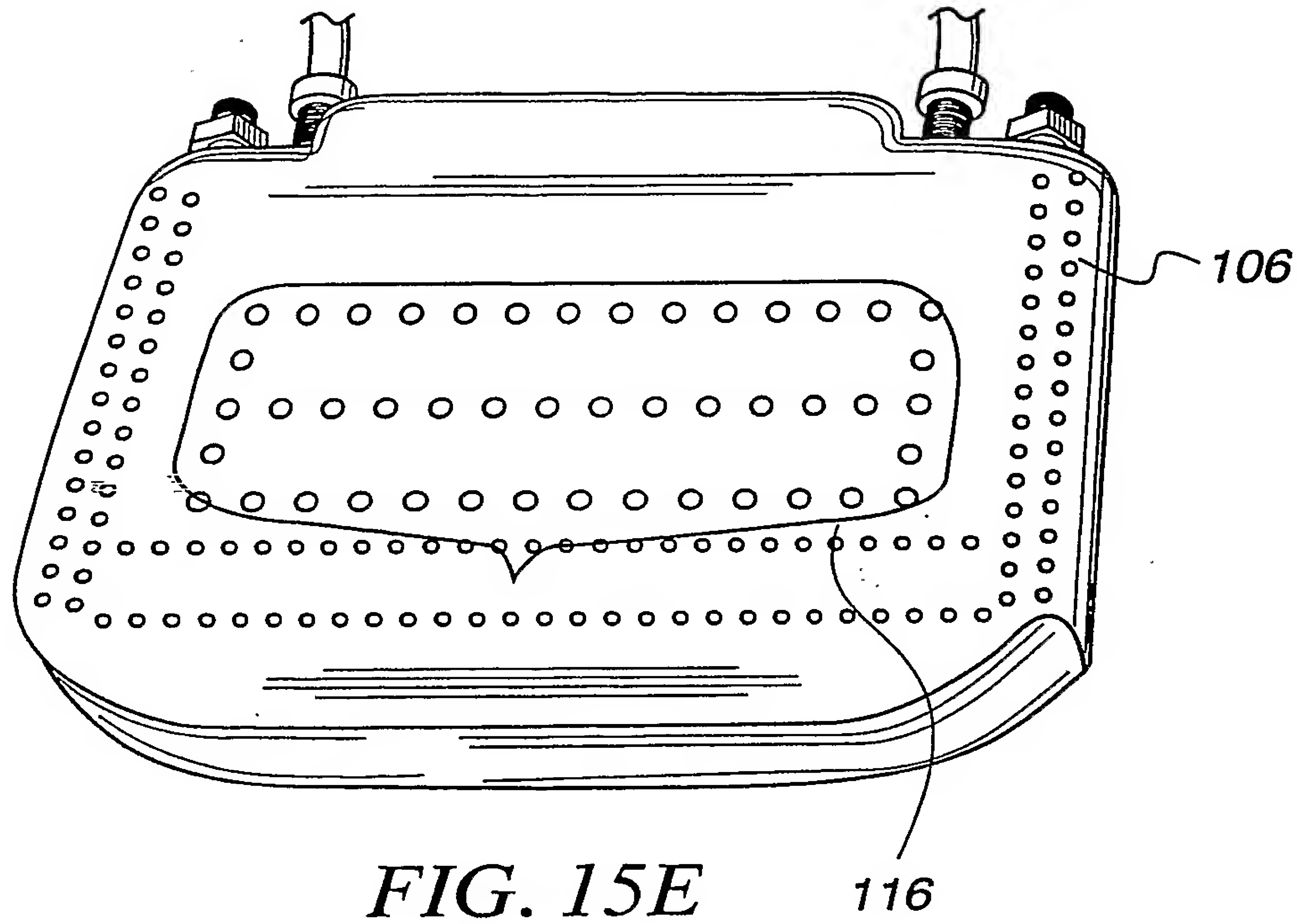


FIG. 15E

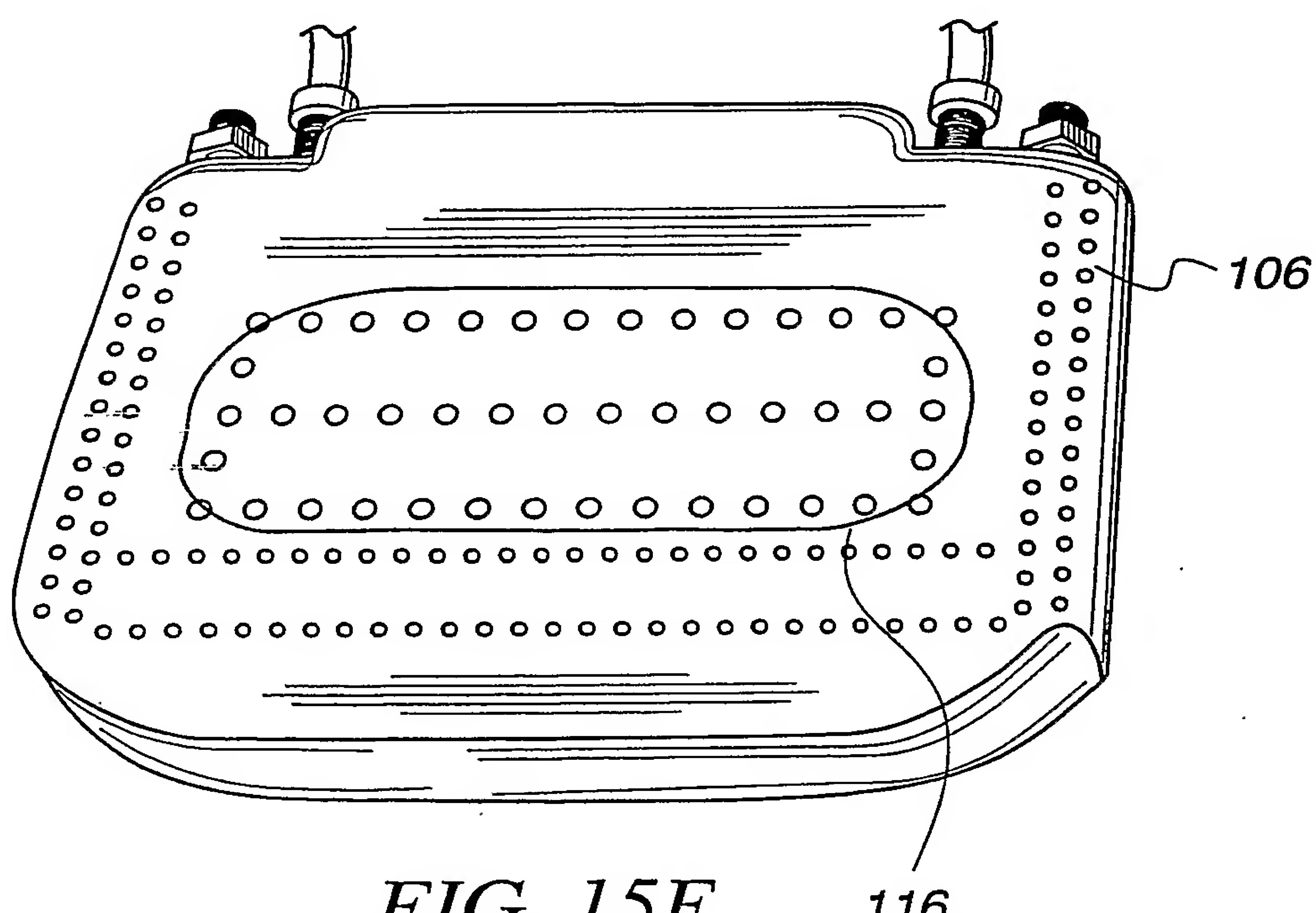


FIG. 15F

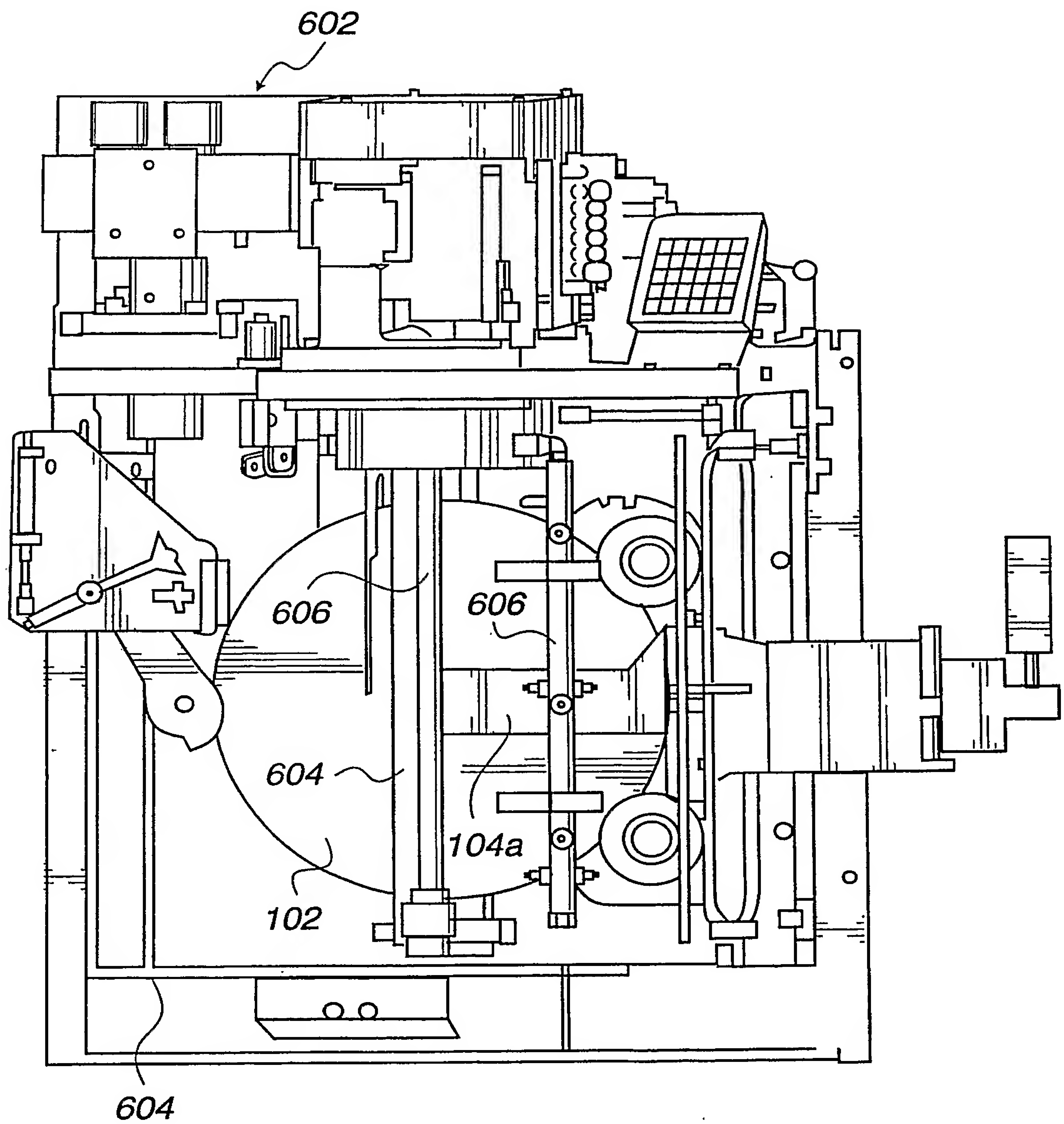


FIG. 16A

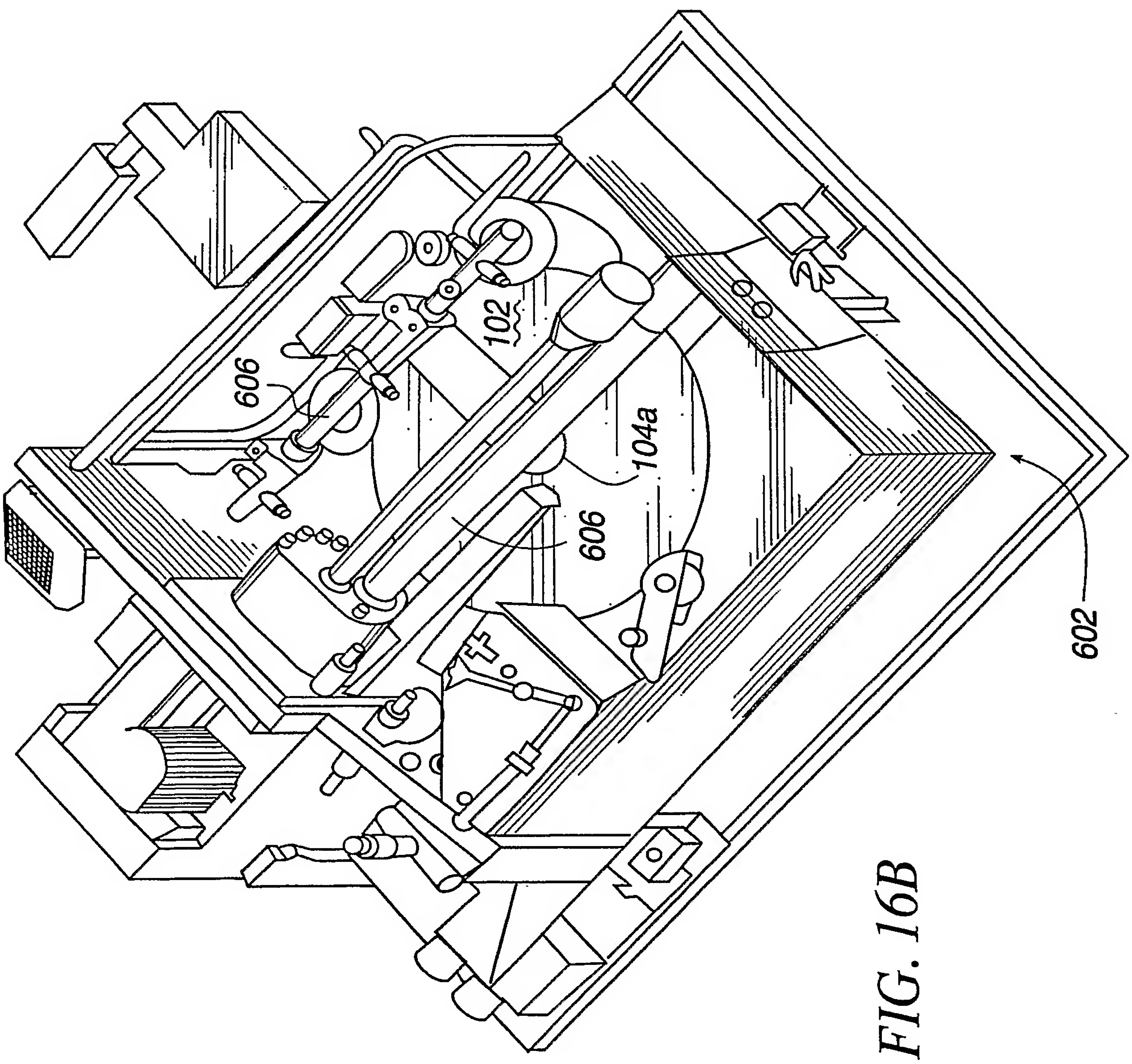


FIG. 16B

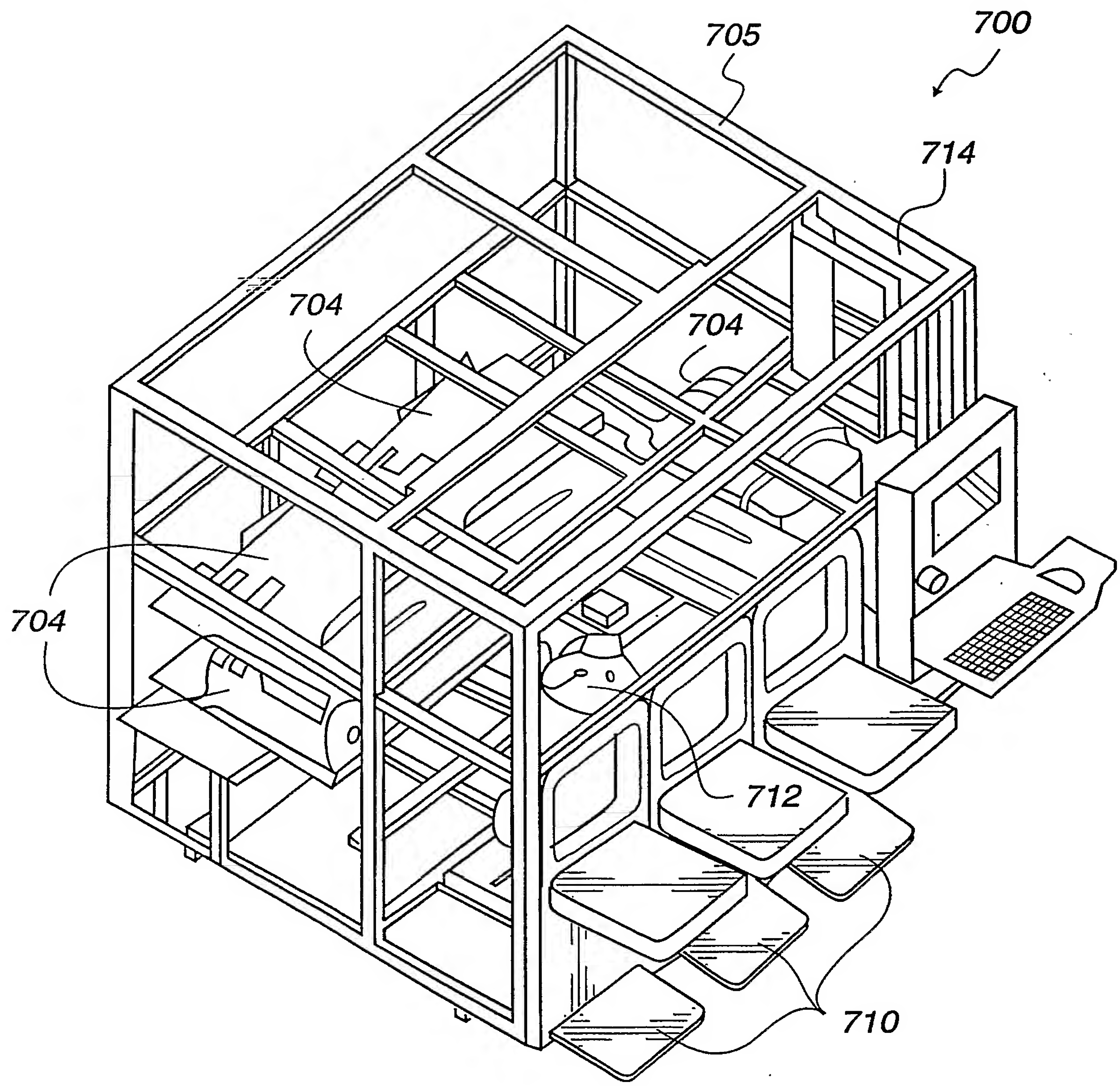


FIG. 17

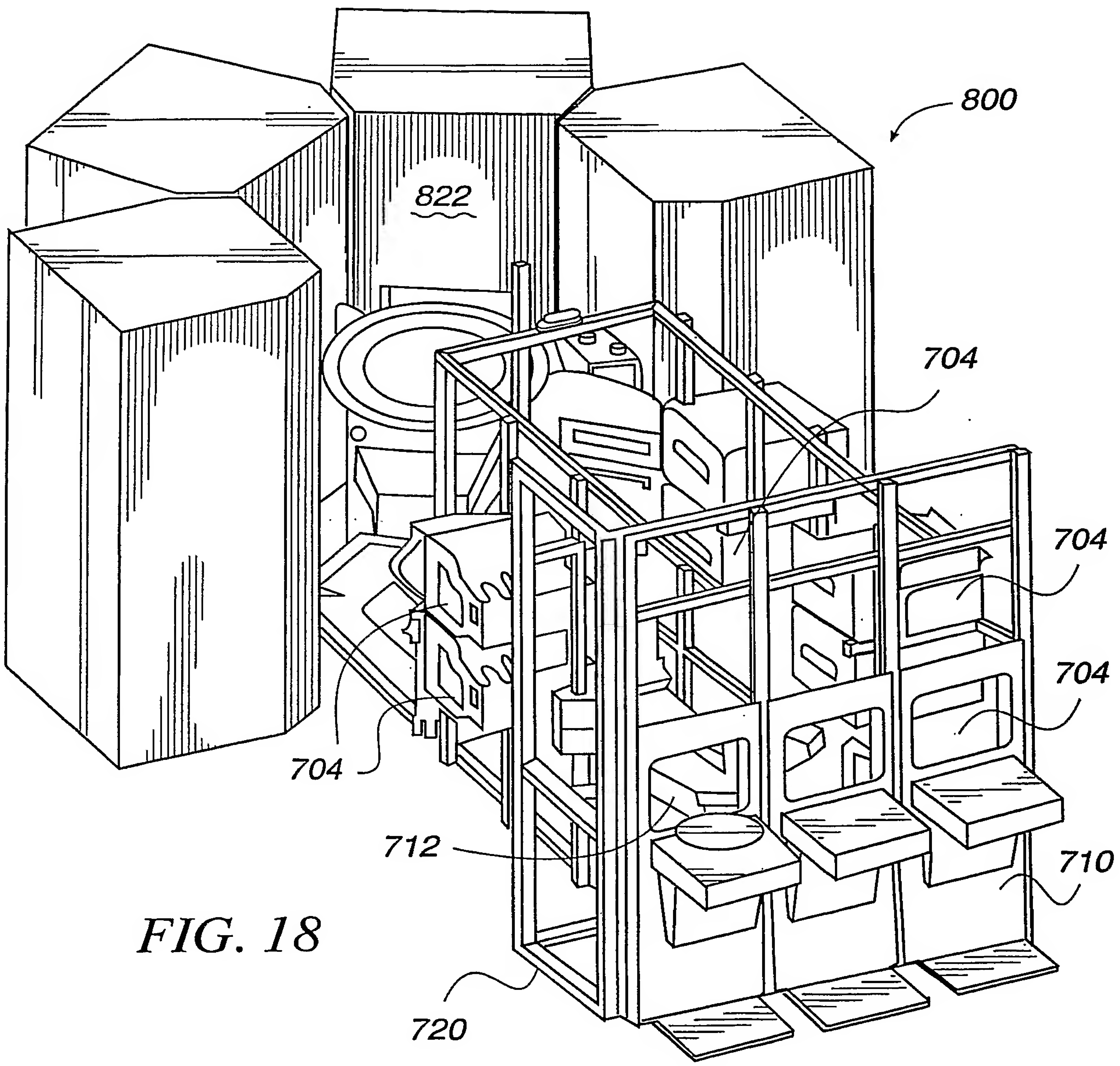


FIG. 18

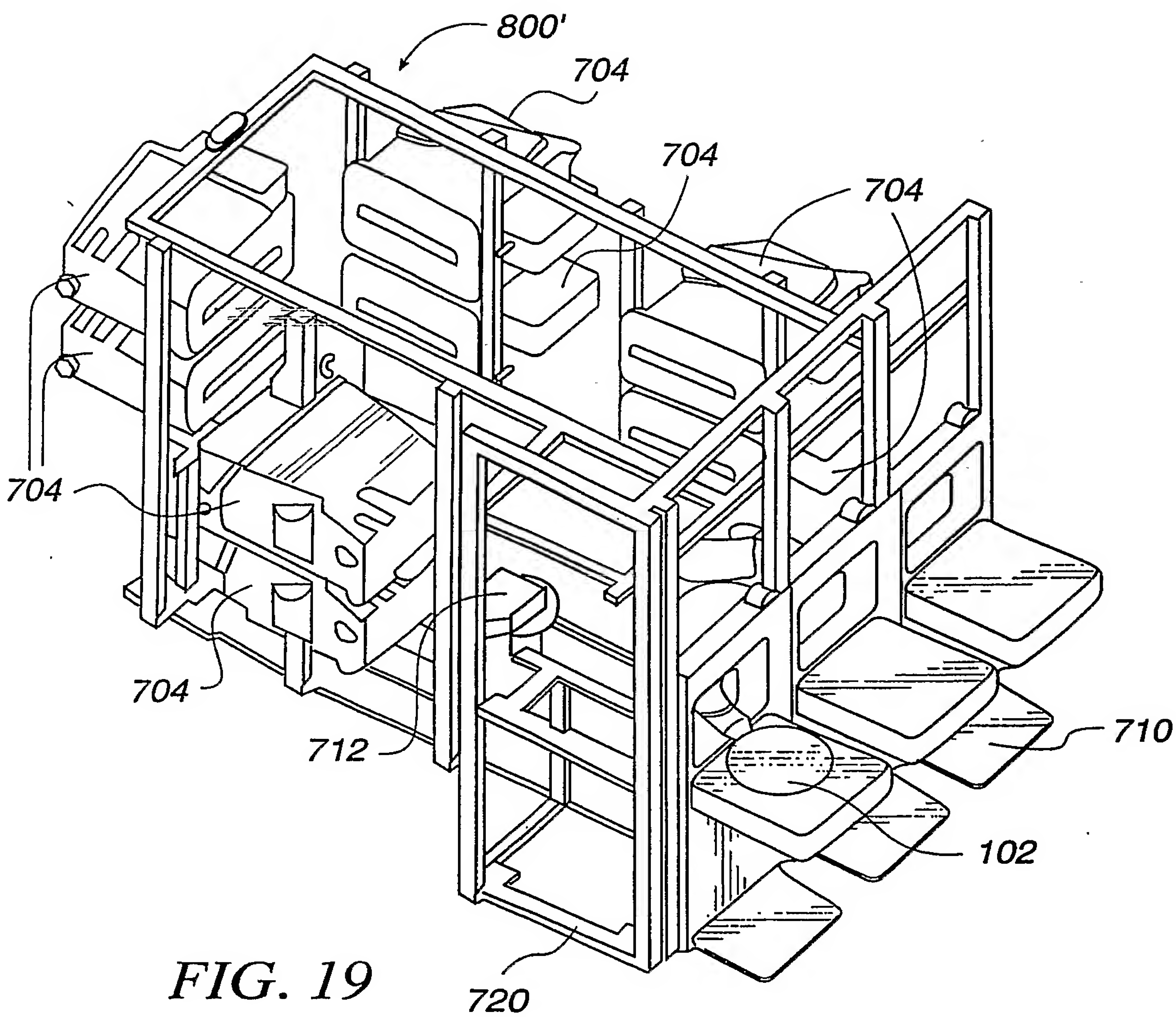


FIG. 19

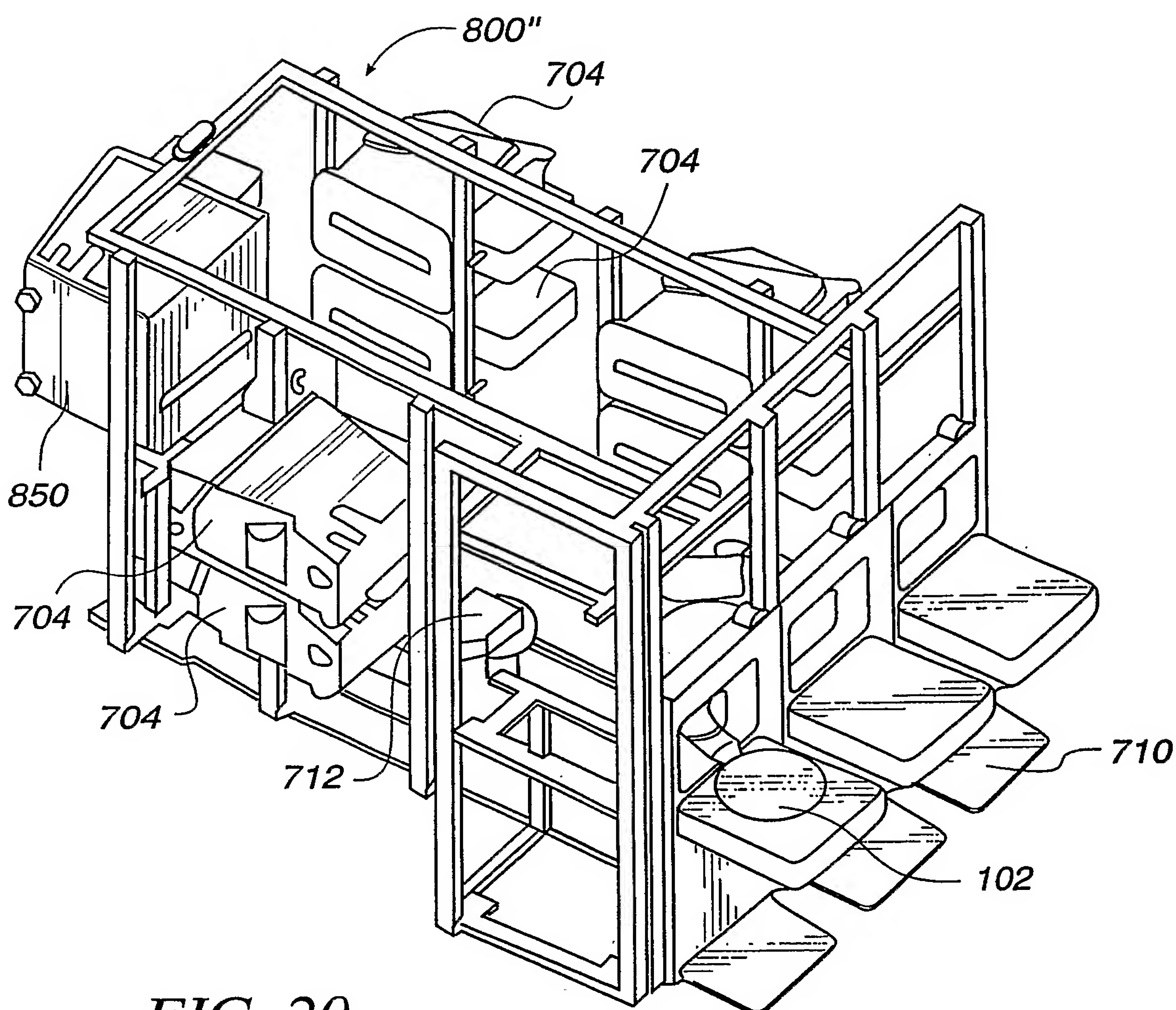


FIG. 20

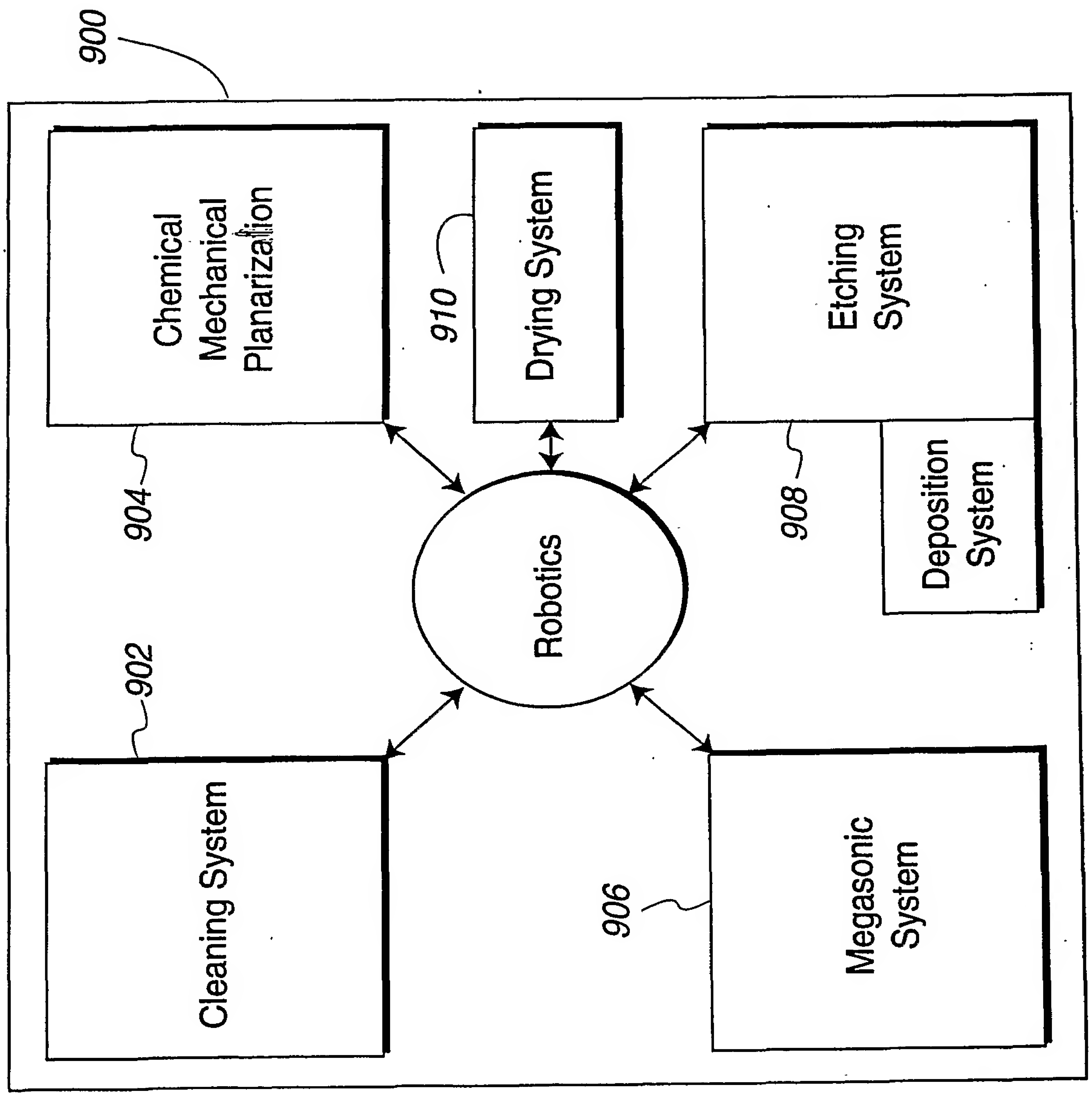

900
Chemical Mechanical Planarization
904
Drying System
910
Etching System
908
Deposition System
Robotics
Cleaning System
902
Megasonic System
906

FIG. 21

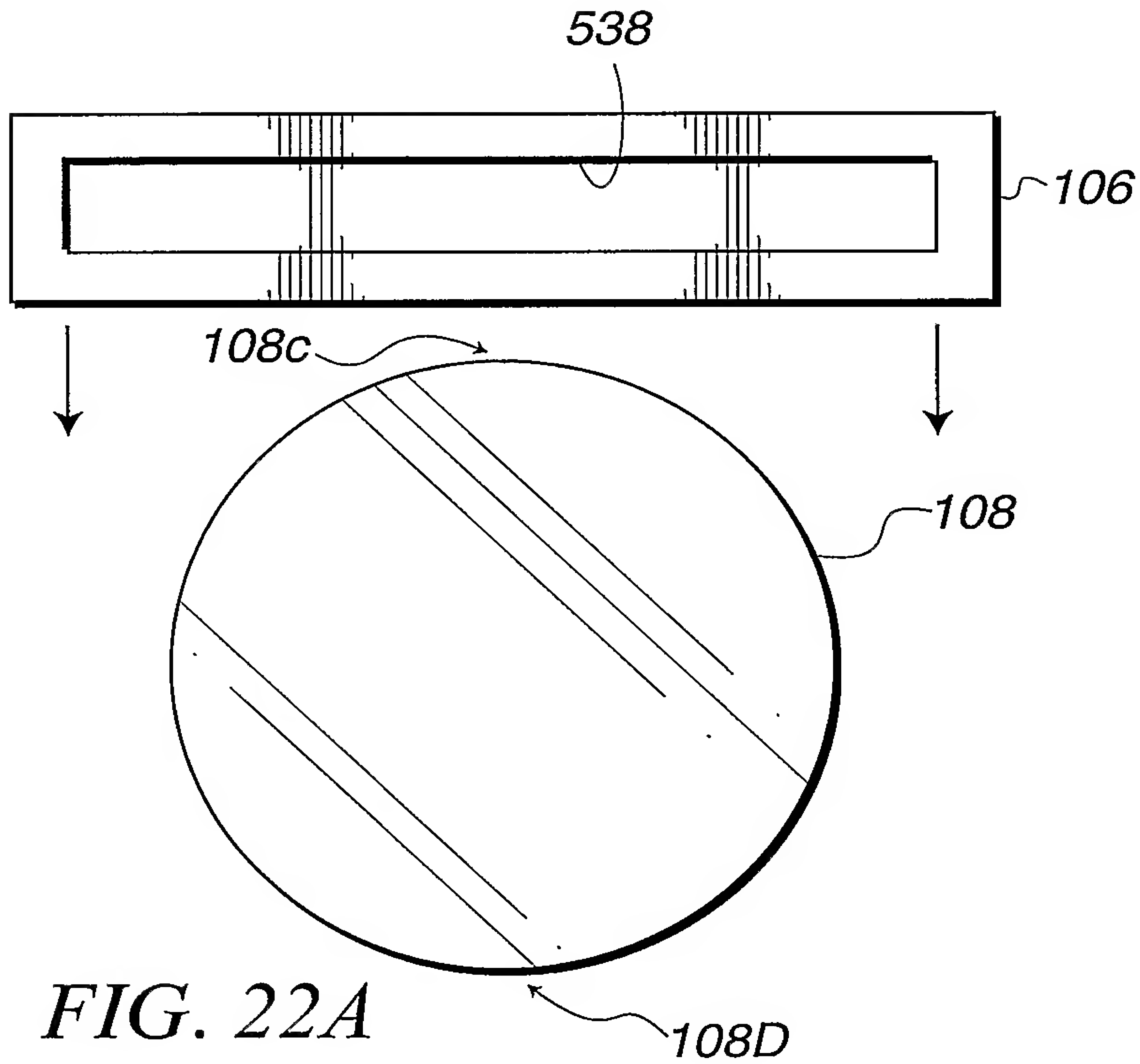


FIG. 22A

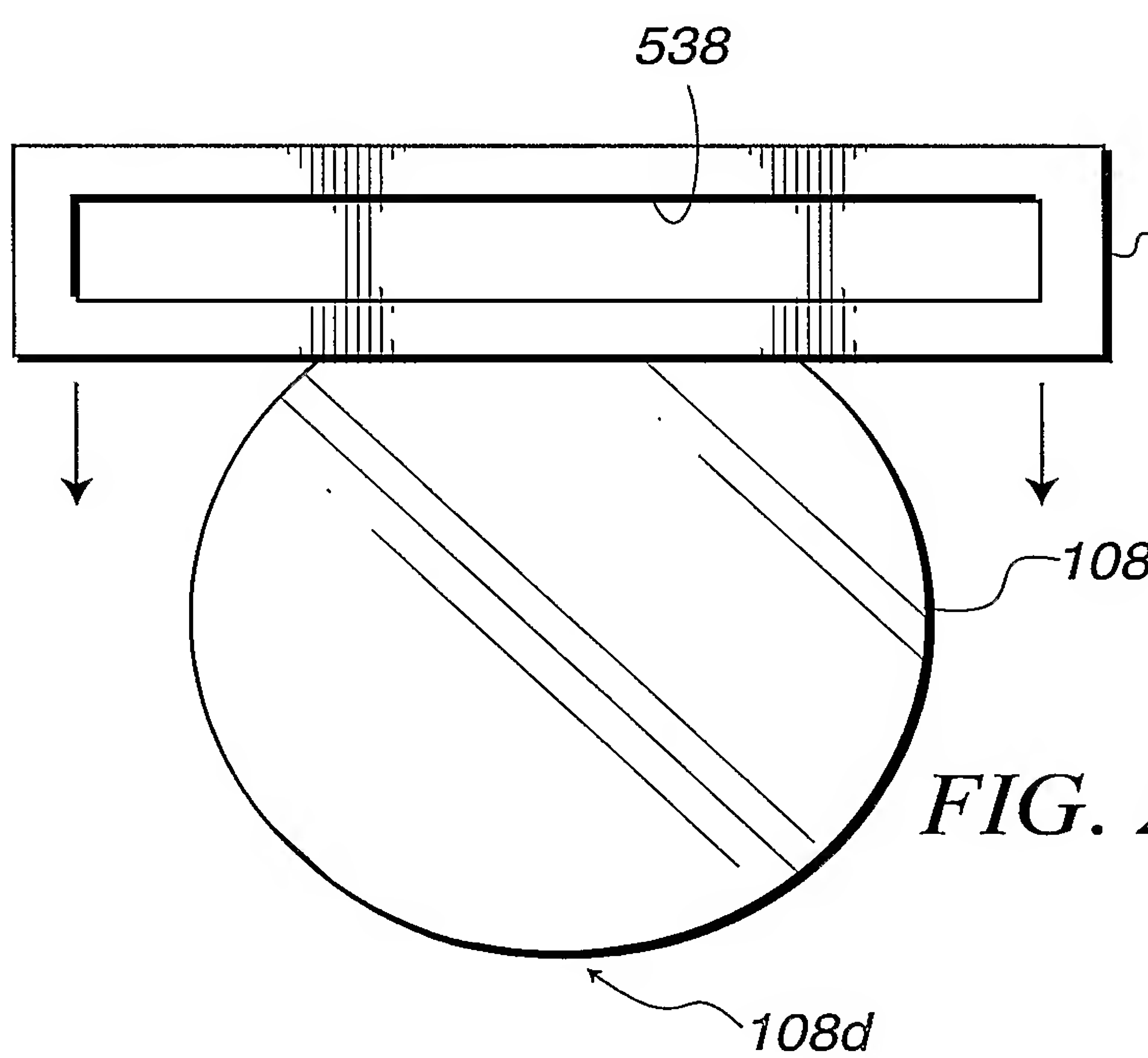


FIG. 22B

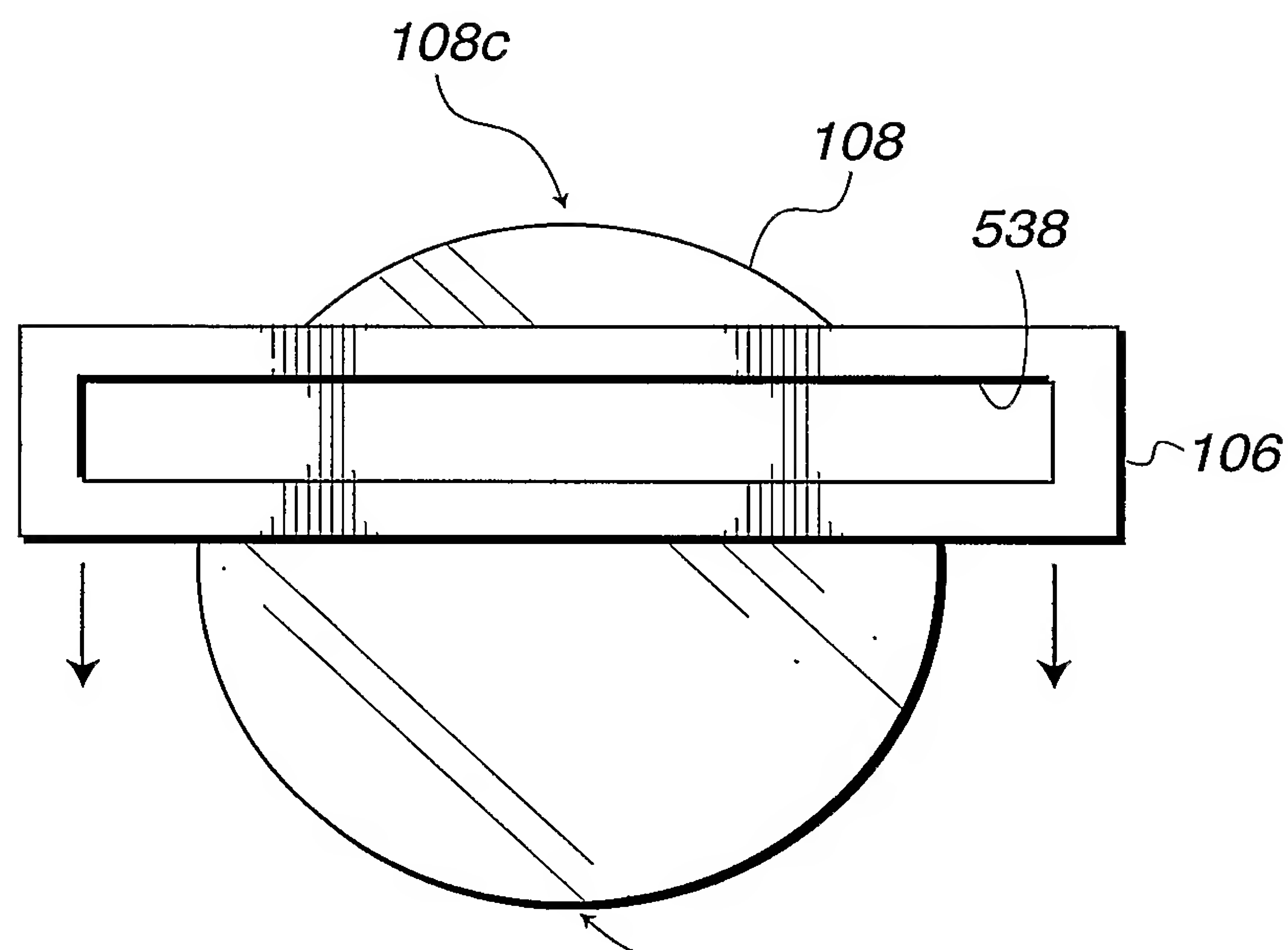


FIG. 22C

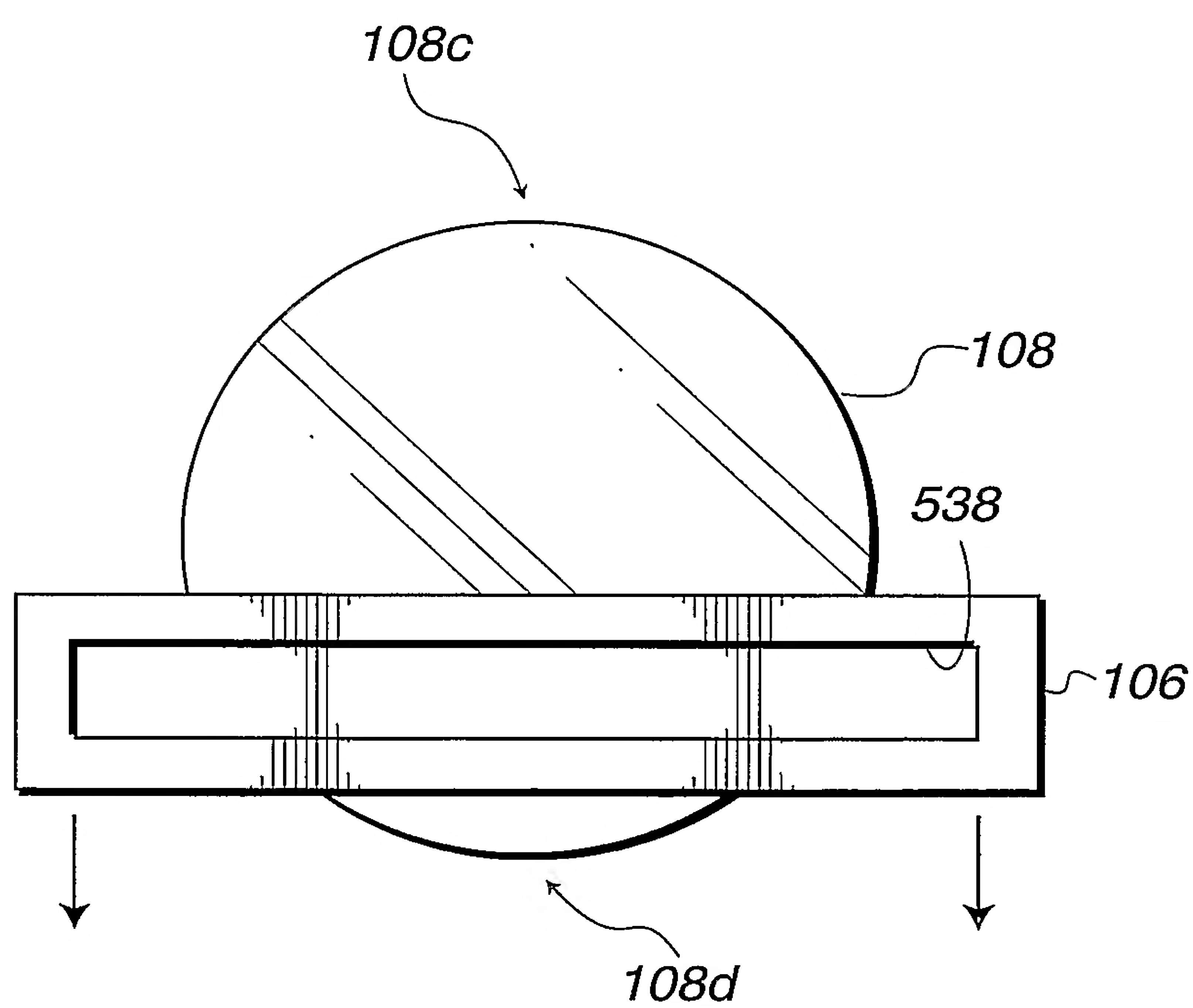


FIG. 22D

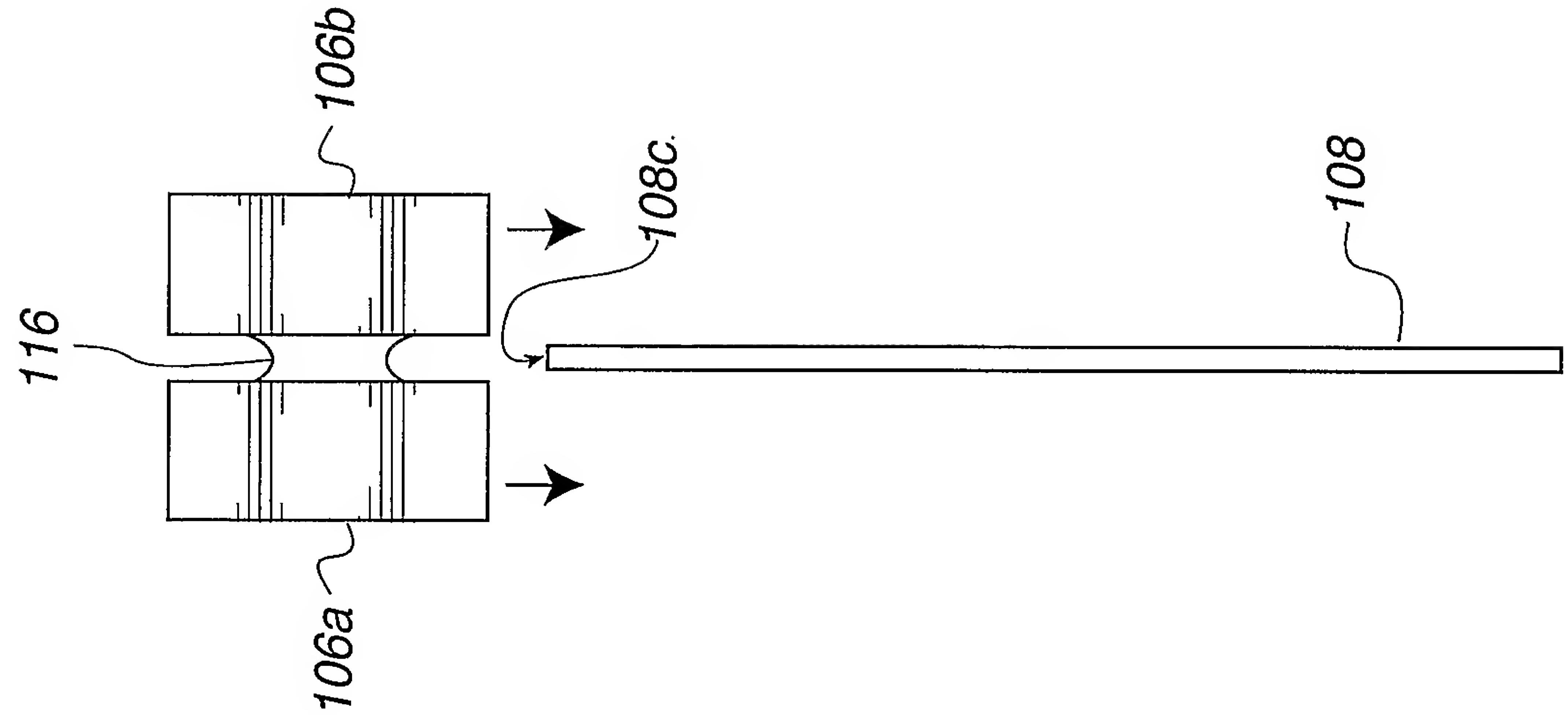


FIG. 22F

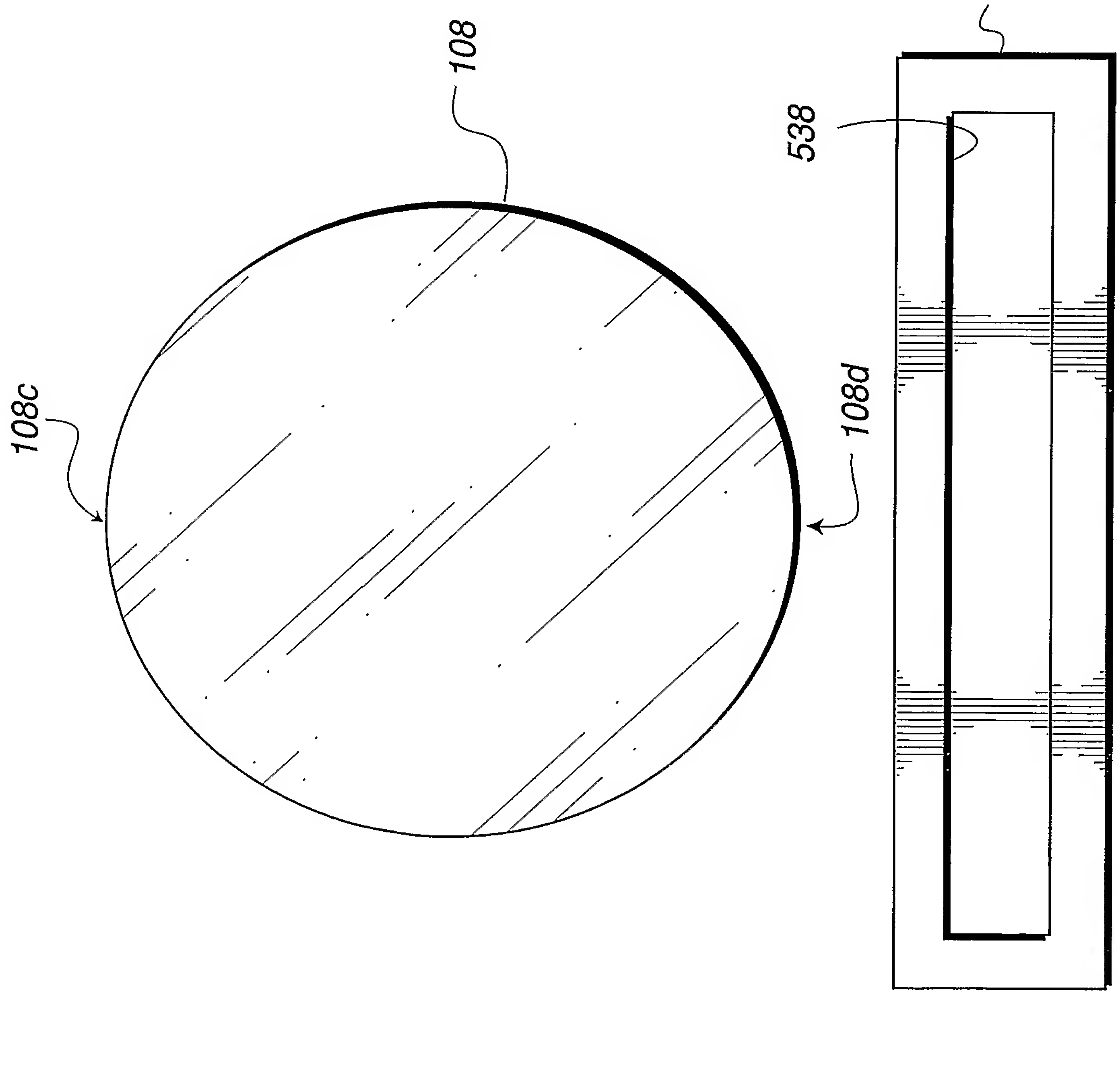


FIG. 22E

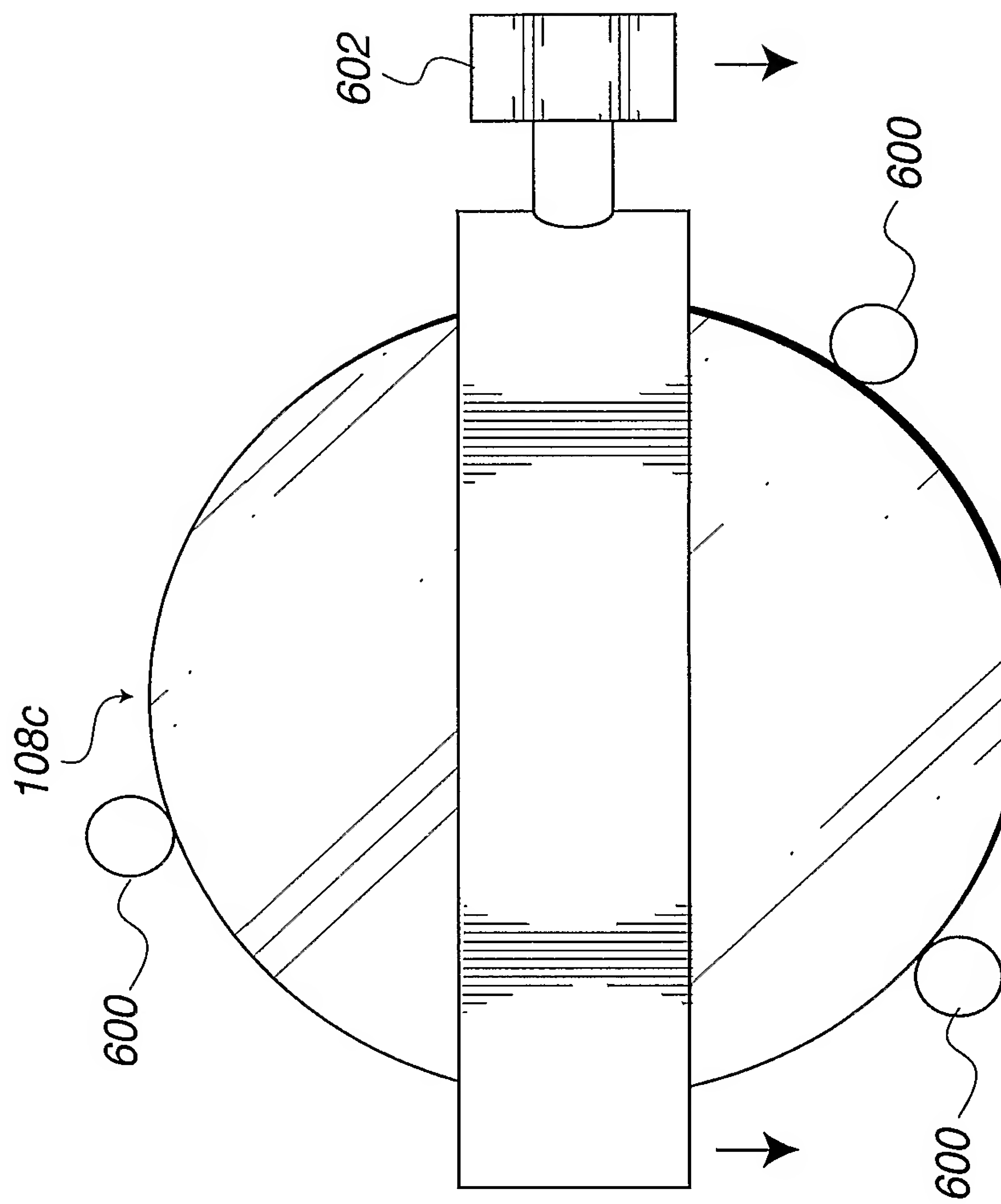


FIG. 23A

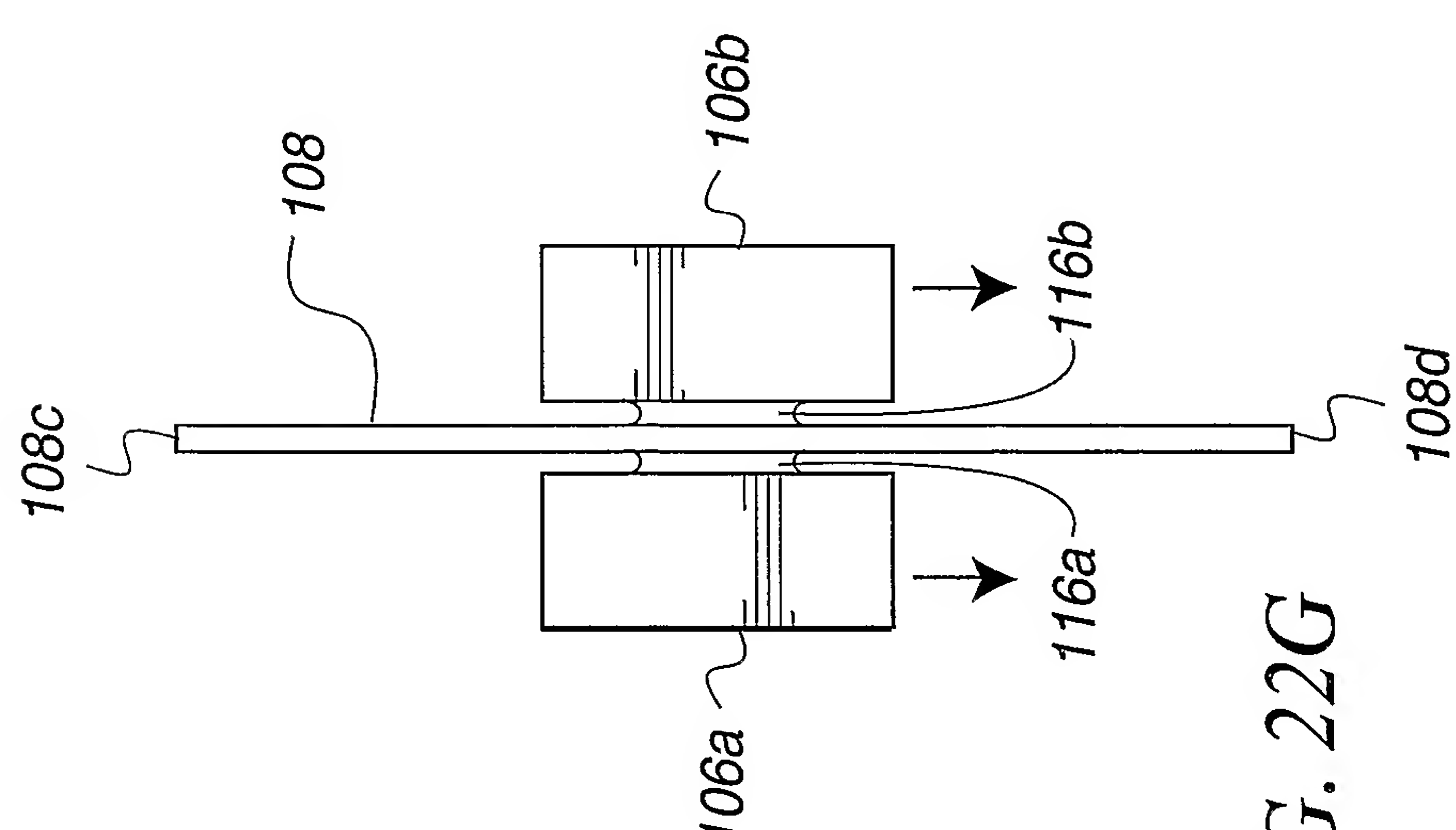


FIG. 22G

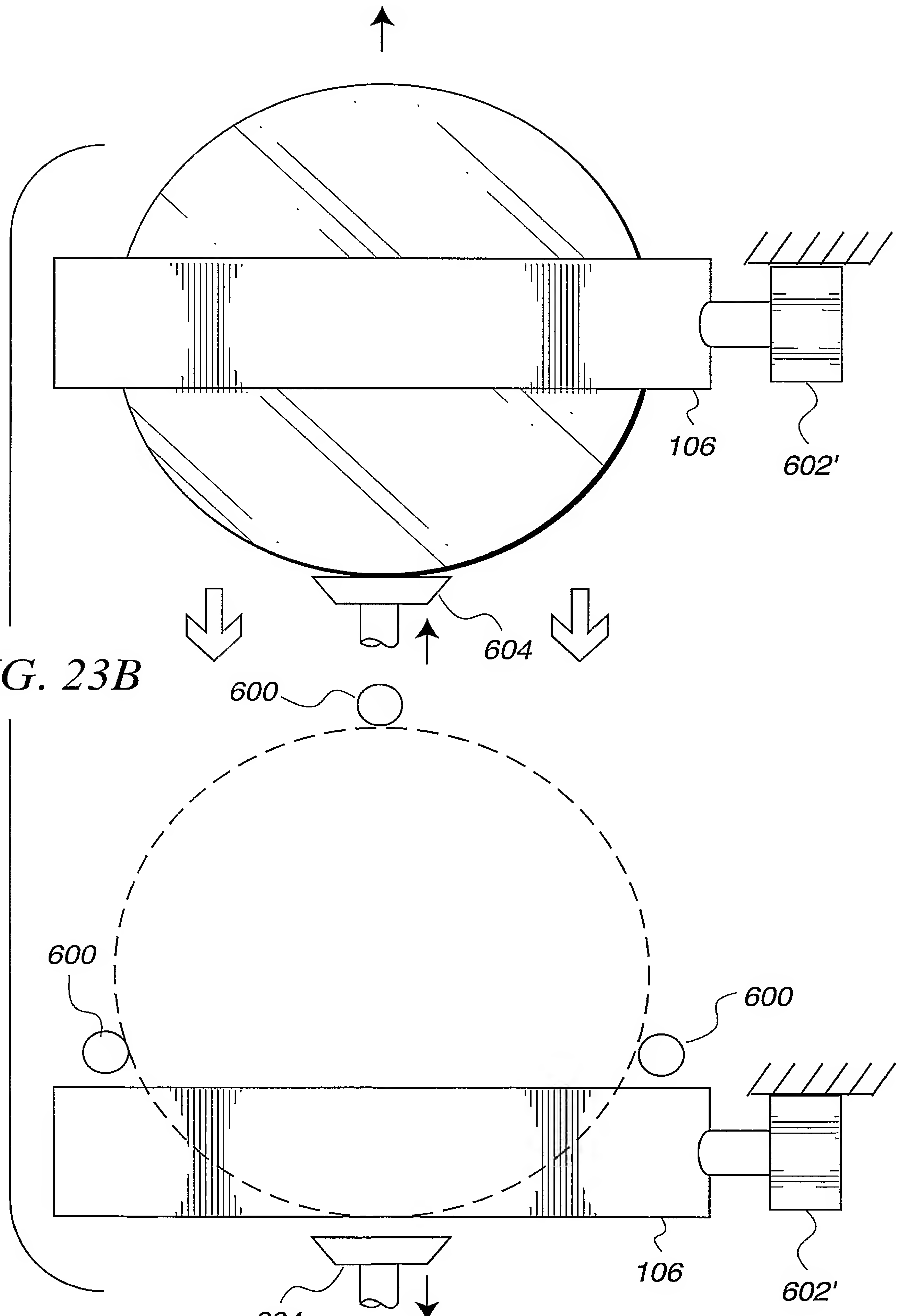


FIG. 23B

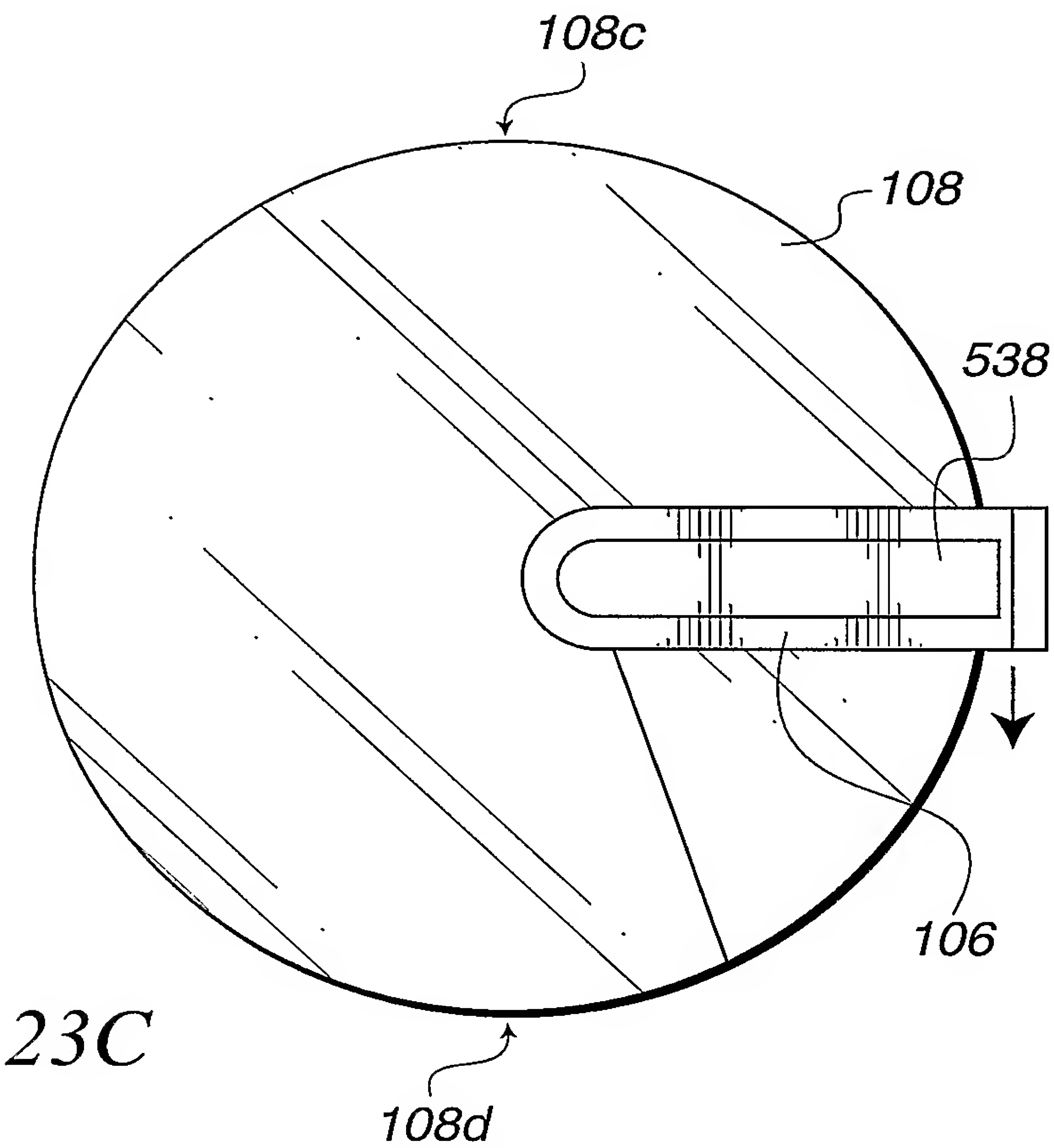


FIG. 23C

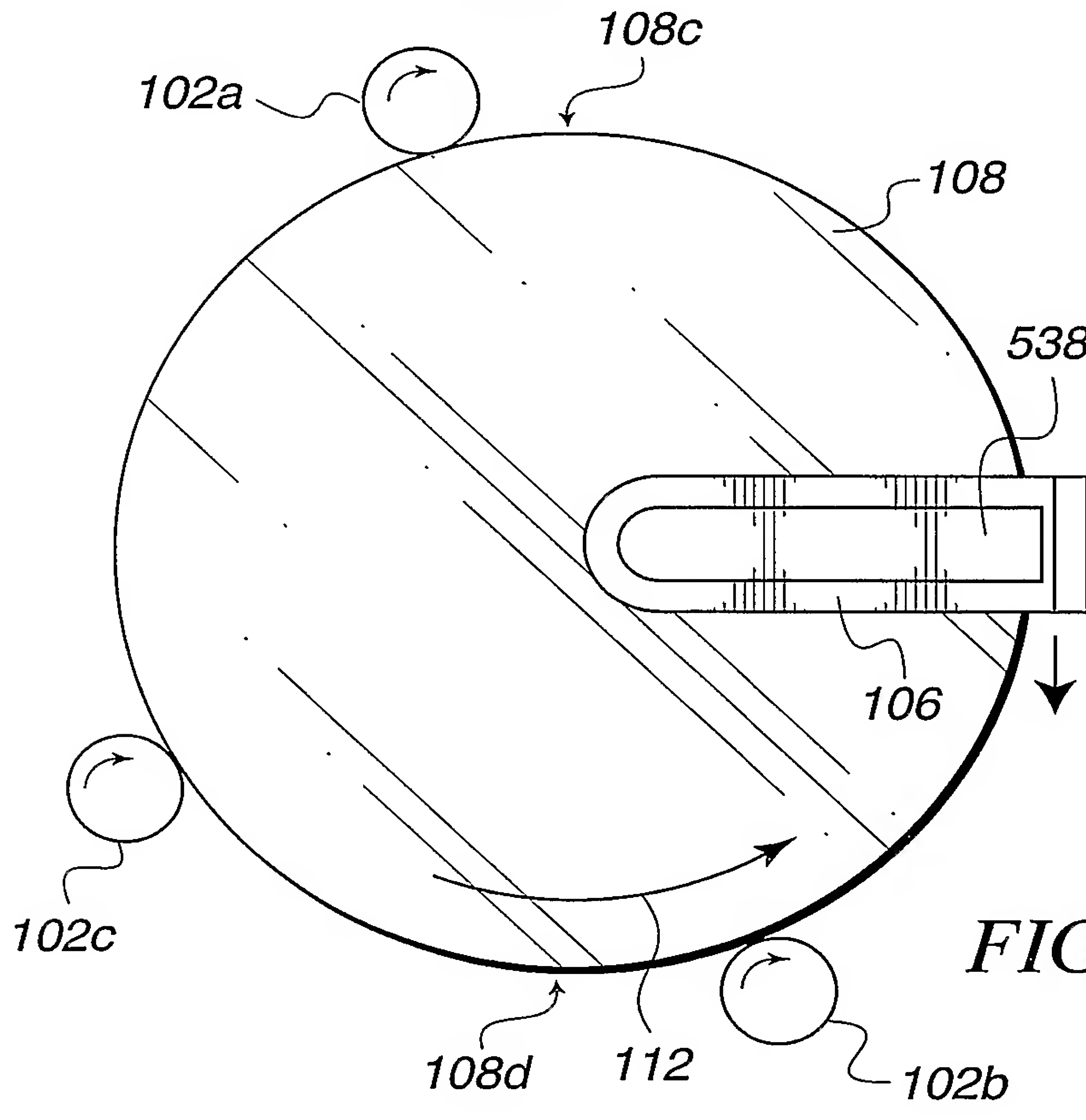


FIG. 23D

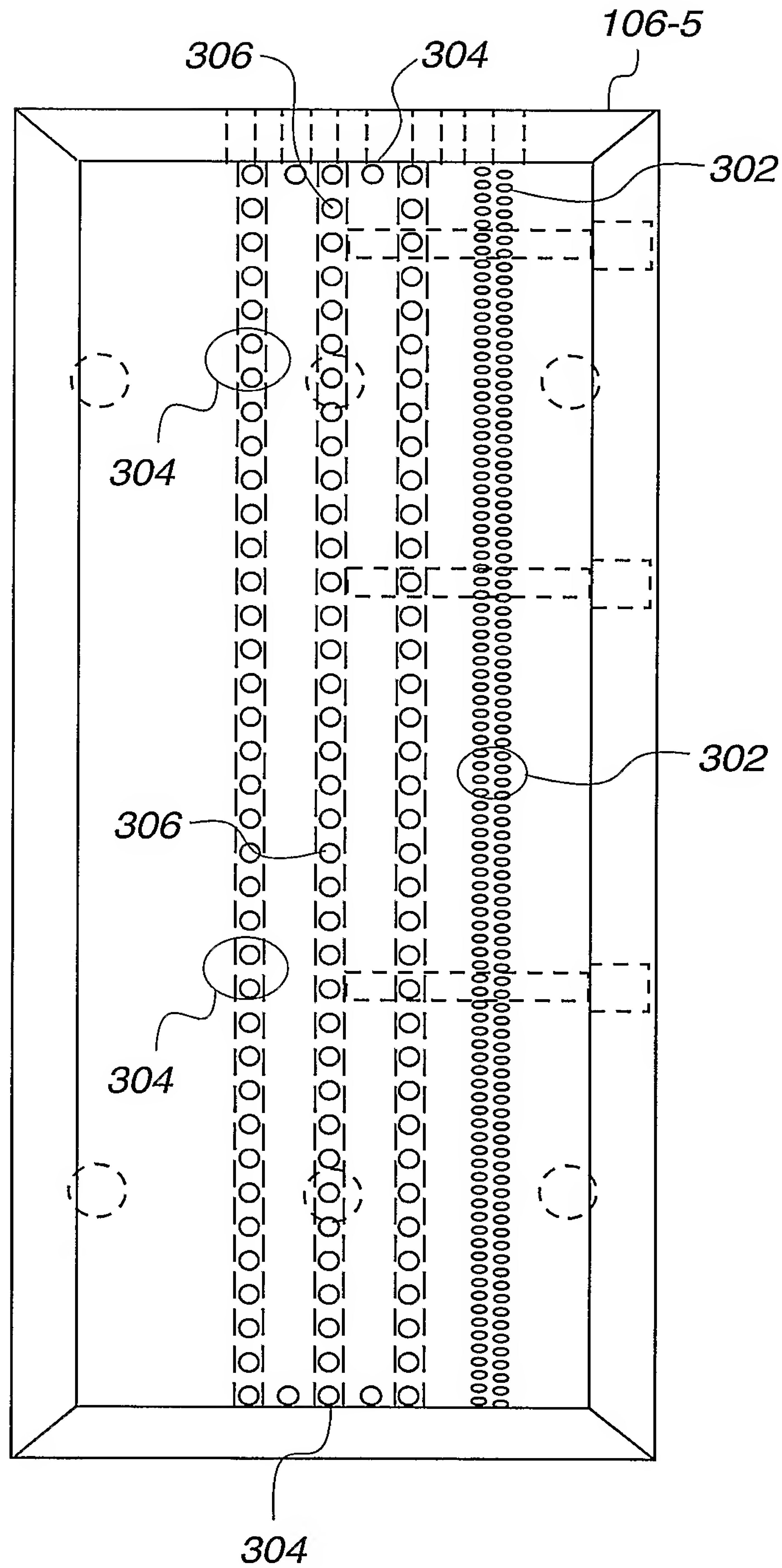


FIG. 24A

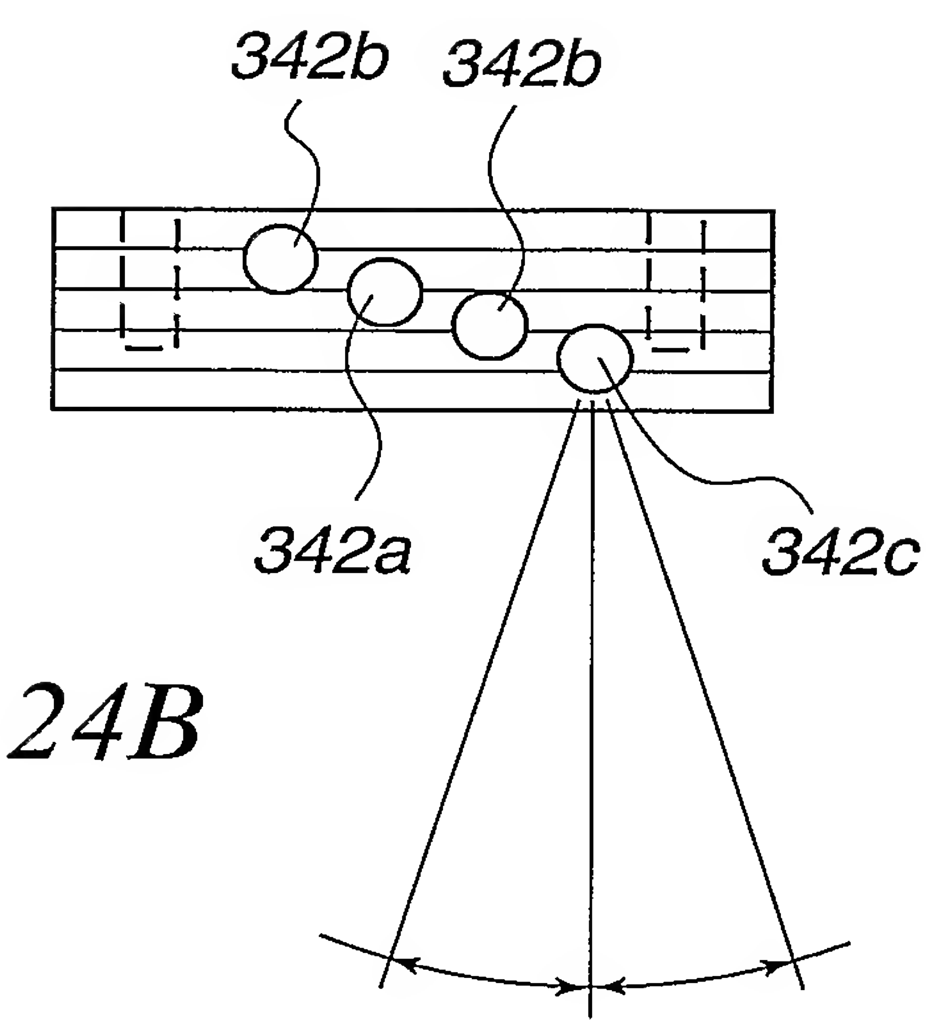


FIG. 24B

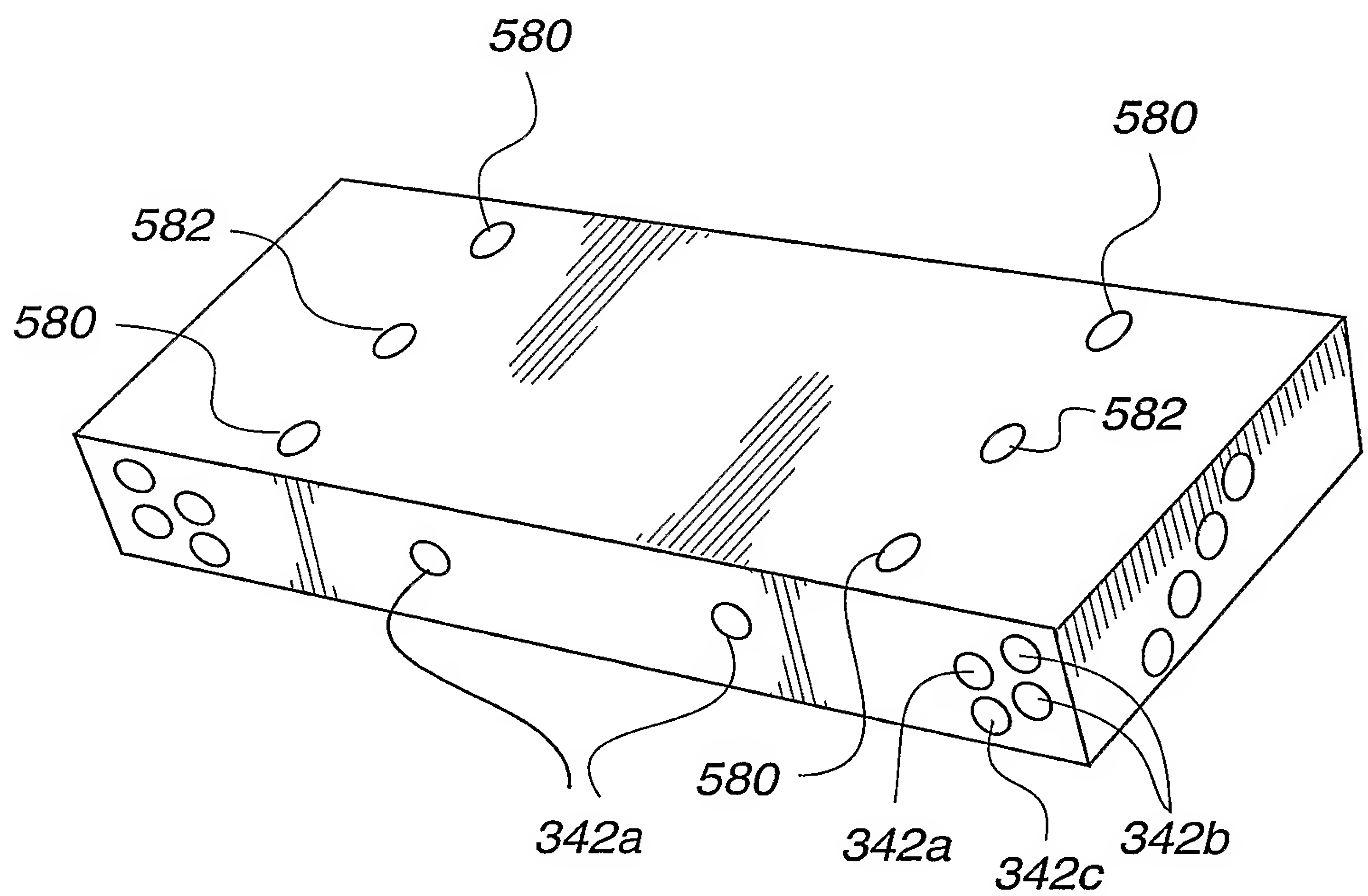


FIG. 24C

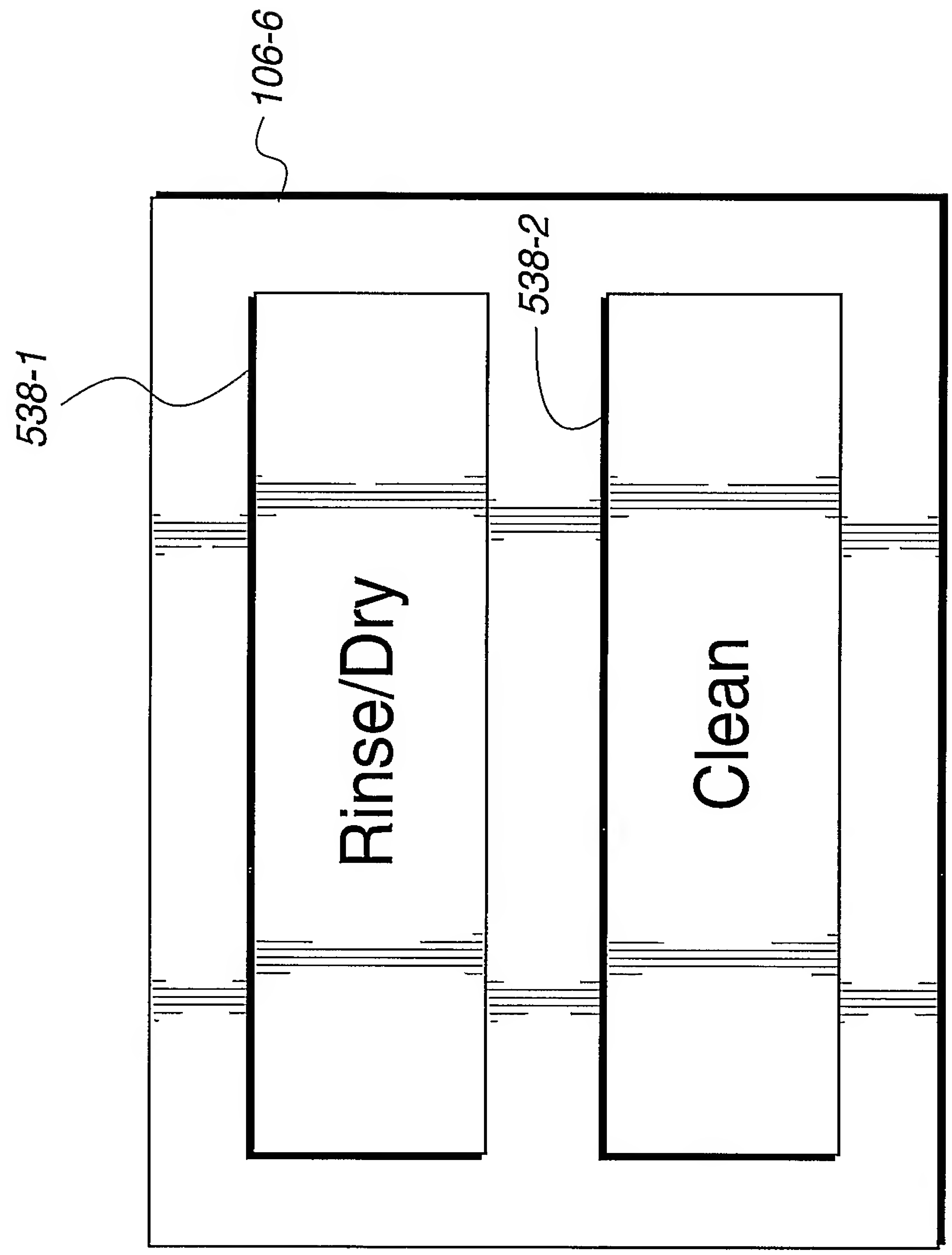


FIG. 25A

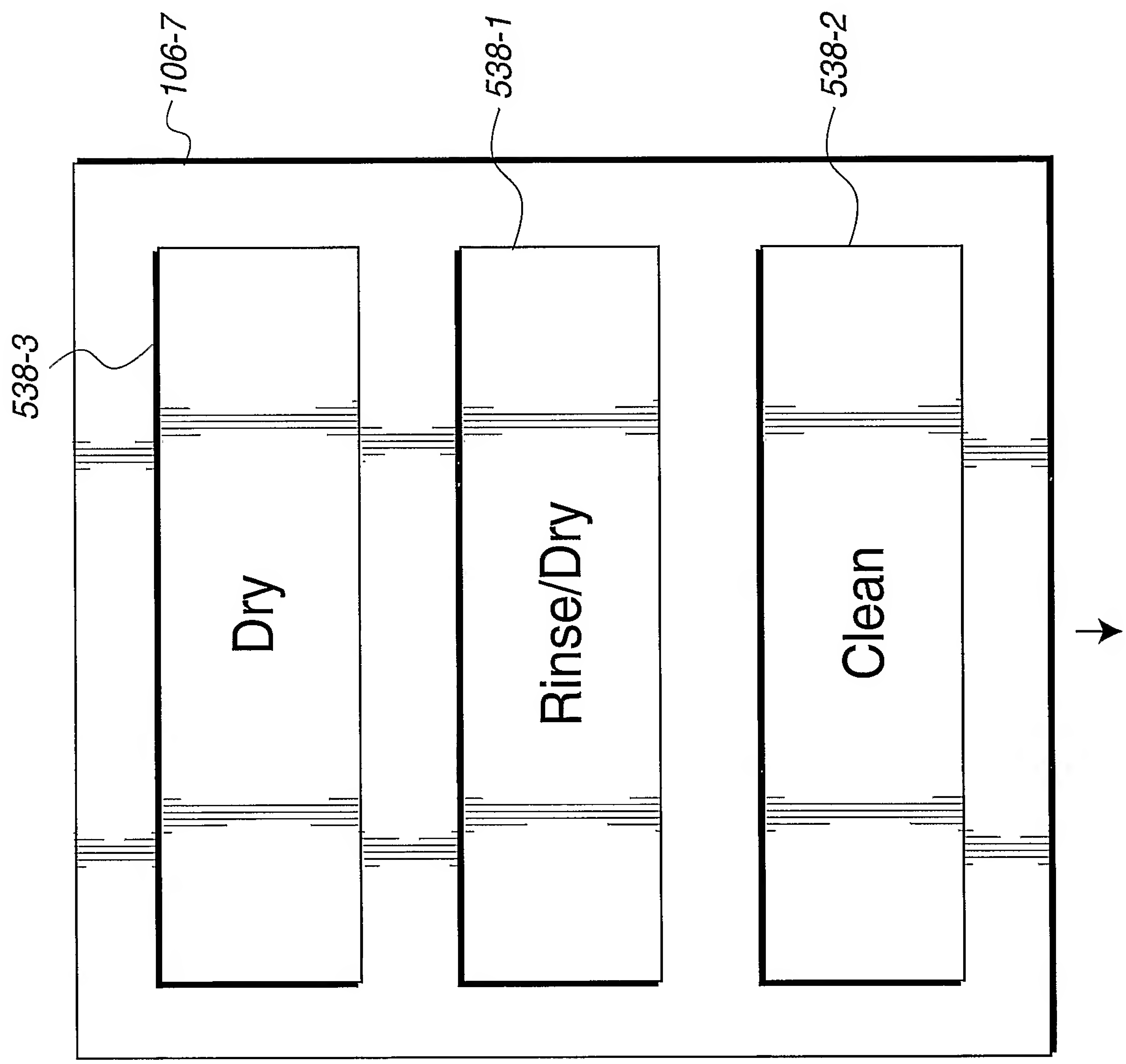


FIG. 25B

PUB-NO: WO2004030051A2

DOCUMENT-IDENTIFIER: WO 2004030051 A2

TITLE: SYSTEM FOR SUBSTRATE PROCESSING WITH MENISCUS, VACUUM, IPA VAPOR, DRYING MANIFOLD

PUBN-DATE: April 8, 2004

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US33084302A (December 24, 2002) ,
US33089702A (December 24, 2002) ,
US40427003A (March 31, 2003)

INT-CL (IPC): H01L021/00

EUR-CL (EPC): H01L021/00 , H01L021/00 , H01L021/00

ABSTRACT:

CHG DATE=20040911 STATUS=O>An apparatus and method for processing a wafer is provided. The system and method are designed to process a surface of a wafer using a meniscus. The meniscus is controlled and is capable of being moved over the surface of the wafer to enable cleaning, rinsing, chemical processing, and drying. The apparatus can be defined using a number of configurations to enable specific processing of the wafer surface using the meniscus, and such configurations can include the use of proximity heads.